International Geology Review

Vol. 1, No. 8 August 1959

- complete table of contents inside -

published by the
AMERICAN GEOLOGICAL INSTITUTE

The American Geological Institute operates under the National Academy of Sciences. It is governed by an Executive Committee and a Board of Directors composed of two directors from each of the fourteen Member Societies.

International Geology Review is published monthly by the American Geological Institute with the assistance of an initiating grant from the National Science Foundation. The journal will report, in English, significant contributions to pure and applied research in the earth sciences which appear in foreign-language journals, especially those published in the U.S.S.R.

The editors of International Geology Review will give consideration to full English translations, condensations, and reviews submitted voluntarily for publication. Translators will be appropriately credited.

Readers are invited to direct to the editors their comments and discussions of articles published in the International Geology Review. Readers are encouraged also to submit suggestions as to published foreign literature considered worthy of translation and publication. Such suggestions should relate to materials of broad, general interest, rather than materials of limited reader interest.

Address editorial and subscription inquiries to

AGI TRANSLATIONS OFFICE
AMERICAN GEOLOGICAL INSTITUTE
2101 Constitution Avenue, N.W., Washington 25, D. C.

The basic subscription rate for International Geology Review is $55 per year, 12 issues. A special subscription rate of $15 per year is available to members of AGI Member Societies who are on the GEOTIMES mailing list and who will pledge to restrict the journal to their personal use. The $15 per year subscription rate is also available to educational institutions and personnel. Foreign postage: No additional charge to Canada and Mexico; to Pan American Union countries add $0.50 per year; to all other foreign countries add $1.00 per year. Single copy price $5.00 ($1.50 to subscribers qualifying for special rates). Second class postage paid at Washington, D. C.

International Geology Review

published monthly by the
AMERICAN GEOLOGICAL INSTITUTE

Vol. 1, No. 8 — August 1959

CONTENTS

REVIEW SECTION

NOTES ON INTERNATIONAL SCIENTIFIC MEETINGS

IGR TRANSLITERATION OF RUSSIAN

The AGI Translation Center has adopted the essential features of Cyrillic Transliteration recommended by the U. S. Department of the Interior, Board of Geographical Names, Washington, D. C.

Alphabet		transliteration
А	а	a
Б	б	b
В	в	v
Г	г	g
Д	д	d
Е	е	e, ye (1)
Ё	ё	ë, yë
Ж	ж	zh
З	з	z
И	и	i (2)
Й	й	y
К	к	k
Л	л	l
М	м	m
Н	н	n
О	о	o
П	п	p
Р	р	r
С	с	s
Т	т	t
У	у	u
Ф	ф	f
Х	х	kh
Ц	ц	ts
Ч	ч	ch
Ш	ш	sh
Щ	щ	shch
Ъ	ъ	" (3)
Ы	ы	y
Ь	ь	' (3)
Э	э	e
Ю	ю	yu
Я	я	ya

However, the AGI Translation Center recommends the following modifications:

1. Ye initially, after vowels, and after ъ, ь. Customary usage calls for "ie" in many names, e.g., SOVIET KIEV, DNIEPER, etc.; or "ye", e.g., BYELORUSSIA, where "e" follows consonants. "e" with dieresis in Russian should be given as "yo".

2. Omitted if preceding a y, e.g., Arkhangelsky (not iy; not ii).

3. Generally omitted.

NOTE: The well-known place and personnel names that have wide acceptance in international literature will be here adopted. However, German-type transliteration e.g., J for Y will not be used.

GEOCHEMISTRY OF ISOTOPES[1]

by

A. P. Vinogradov[2]

• translated by V. P. Sokoloff •

ABSTRACT

The isotopic composition of the earth's crust is never static, due to various radioactive processes. This is especially noticeable on geologic time scales. The isotopic exchange reactions, particularly those involving lighter atoms, are intensive in the outer shell of the earth, notably in the biosphere. The biospheric exchange reactions are primarily responsible for local enrichments and anomalous absences of various isotopes, especially those of oxygen, carbon, sulfur, and hydrogen. Isotope geochemistry is a tool which will help solve problems of past major and minor geologic events in the genesis of rocks and minerals. It is hoped that isotope geochemistry will introduce two new parameters into geologic investigation of time and temperature of natural processes. --G. E. Denegar.

It has been established that many chemical elements are mixtures of isotope-atoms having equal charges but different masses, with the differences corresponding to the mass of one or more neutrons. Isotopes of several elements have been obtained in appreciable quantities. It has become possible accordingly to investigate their properties--and this has contributed significantly to the success of nuclear physics and of associated sciences.

More and more frequently, in laboratory experiments of physicists, chemists, and other investigators, isotopes, rather than chemical elements, are used in mass spectrometry and other methods of determination; isolation of isotopes is used now at many research institutes. Thus isotopes had acquired a high theoretical and practical significance in chemistry, biology, technology, and other fields of knowledge. An industry dealing with procurement of both stable and radioactive isotopes, as well as with their utilization, has developed.

Originally, research interests in geochemistry were bound chiefly to the behavior of radioactive isotopes in natural environments. Later, as the scientific value of isotope studies increased, geochemical studies of stable isotopes also made their appearance. We must remember V. I. Vernadsky, in this connection, who was so insistent in posing these problems before scientists--with his characteristic scientific foresight.

One of the fundamental problems in geochemistry is a clarification of regularities in the spread and in the distribution of chemical elements. It is reasonable therefore to expand such geochemical studies in the direction of the abundance and the distribution of isotopes of individual elements in geologic materials. The problem of distribution of different atom species in the earth and cosmos formerly studied by geochemists is now being solved chiefly by physicists and astrophysicists, on the bases of nuclear structures.

It is possible to maintain that distribution of isotopes in the earth is not random but is related to structures of atomic nuclei. However, we still have no completed theory in this respect. Some individual empirical regularities are known which permit us to understand the basic pattern of isotope distribution in the earth and to compare this pattern with those of other cosmic bodies. Thus, for example, it is well known that the most widely distributed isotopes contain even numbers of protons ("p") and of neutrons ("n^o") in their nuclei. Because of the mutual compensation [Tr.: in original "saturation"] of the nucleon couples in the even nuclei, they remain most stable, for example, with respect to beta decay. The relative abundance is especially high for those of the even-numbered atoms whose mass number is also a multiple of 4, that is, a multiple of the alpha particle such as C^{12}, O^{16}, Ca^{40}, Fe^{56}, and others.

About 60 percent (192 of the total 330) of isotopes exist in nature even with respect to "p" as well as "n^o" of their atoms. The number of isotopes even in "p" and odd in "n^o" is 65, or about 20 percent of the total. There are 54 isotopes odd in "p" but even in "n^o", or about 16 percent of the total. Finally, there are 16 isotopes odd in "p" and odd in "n^o", or about 5 percent of the total. These include not only the stable but all the natural radioactive isotopes. If, however, we take into account only the stable ones, their number becomes only four: D^2, Li^6, B^{10}, and N^{14}, that is, about 1 percent of the total.

These and certain other regularities in the relative abundance of isotopes permit us even now, as well as in the future, as our knowledge increases, to detect some anomalous abundances and to discover accordingly new processes responsible for changes in the isotopic ratios of the earth. Undoubtedly, some isotopes disappear and others are born in the earth, in its rocks,

---

[1] Translated from Geokhimiya izotopov: Akademiya Nauk SSSR, Vestnik, 1954, no. 5, p. 26-43.

[2] Academician, Academy of Sciences, U.S.S.R.

water and gases.

Stable isotopes, He^4, Pb^{206}, Pb^{207}, Pb^{208}, are originated as the result of the self-induced decomposition of U^{238}, U^{235}, and Th^{232}. We know also that several other weakly radioactive isotopes which yield stable isotopes, for example, Ar^{40} and Sr^{87}, as endproducts of their decomposition (table 1). As a result of the spontaneous division of uranium and thorium and, it appears, of their division by the thermal neutrons originating in natural bodies themselves, the inert gases, Xe, Kr, and Ar, as well as the transuranium elements, Pu, Np, and others, are formed.

TABLE 1. Products of radioactive decomposition

Formation of stable isotopes by radioactive decomposition		Half-life (years)
U^{238} $(\alpha, \beta^-, \gamma)$	$\to Pb^{206}$, He^4	$4.50 \cdot 10^9$
U^{235} $(\alpha, \beta^-, \gamma)$	$\to Pb^{207}$, He^4	$7.07 \cdot 10^8$
Th^{232} $(\alpha, \beta^-, \gamma)$	$\to Pb^{208}$, He^4	$1.39 \cdot 10^{10}$
Bi^{209} α	Tl^{205}	$\sim 3 \cdot 10$
Re^{187} β^-	$\to Os^{187}$	$5.8 \cdot 10^{12}$
Lu^{176} β^-, E	$\to Hf^{176}$, $\to Yb^{176}$	$2.4 \cdot 10^{10}$
La^{138} E	$\to Ba^{138}$	$1.2 \cdot 10^{11}$
Sm^{147} α	$\to Nd^{143}$	$1.3 \cdot 10^{11}$
I^{129} β^-	$\to Xe^{129}$	$>10^8$
Sn^{124} $2\beta^-$	$\to Te^{124}$	$6 \cdot 10^{15}$
In^{115} β^-	$\to Sn^{115}$	$6 \cdot 10^{14}$
Rb^{87} β^-	$\to Sr^{87}$	$6 \cdot 10^{10}$
K^{40} β^-, E	$\to Ca^{40}$, $\to Ar^{40}$	$1.2 \cdot 10^9$

Note: underscoring indicates isotope couples employed in age determination.

The penetrating cosmic radiations are also responsible for nuclear reactions giving rise to new isotopes, C^{14}, H^3, and He^3. New discoveries may be anticipated also in this field.

Finally, as we shall see further on, there are processes operative in the earth by which the isotope ratios are distributed, especially in the case of stable low-weight isotopes, and local enrichments or impoverishments, with respect to this or that isotope, are brought about. In such manner, the isotopic composition of the earth is continuously undergoing change. The short-lived isotopes disappear; new stable isotopes take their place. Such losses or accessions of isotopes, as we shall see, are noticeable beyond any doubt on the time scale of the earth.

The same examples of natural isotope relationships which I intend here to discuss, so as to show in what manner they can be used in solution of different geologic problems, give us also an idea of the span of variations in isotope ratios observed in nature for several elements. I have in mind the problem of age; of the composition of the atmosphere; and of the geochemistry of oxygen, carbon, sulfur, and hydrogen isotopes in the light of their isotope relationships.

Age of the earth and of rock, the time span of their existence, is calculated from the moment of their latest solidification. Let us examine results on age of the earth, as determined by the isotopic composition of ordinary lead (chiefly as galena) associated with rocks of different geologic age, young and very ancient. Ordinary lead is a mixture of four isotopes, Pb^{204}, Pb^{206}, Pb^{207}, and Pb^{208}. The latter three are accumulated in rock as a result of the radioactive decomposition of U^{238}, U^{235}, and Th^{232}, respectively. Pb^{204} is not being accumulated at this time and its origin is not known. Pb^{208}, derived from thorium, is radiogenic in part. $Pb^{208}$is "twice-magic" and its amounts in natural lead are insignificant. Apparently a part of Pb^{208} is older than the earth. It is the Pb^{206} and Pb^{207} isotopes that are of interest to us. We determined lead in 32 samples. Together with the earlier determination by Nier and the subsequently published more recent isotopic analyses of lead, we have the total of 90 determinations at our disposal. Geologic age of this lead ranges from 20 million to 2.5 billion years. The proportions of Pb^{206} and Pb^{207} in natural lead show regularity in their variations. The earlier the lead had become separated from the rock--and isolated from Th and U accordingly--the lower is its content of Pb^{206} and Pb^{207}, and vice versa (table 2).

All samples were classified according to the age of rocks from which the mineral specimens were obtained, as indicated by geologists (I wish to emphasize this). The approximate determination of the age by geologists was taken as the basis of the grouping. These groups, as shown in table 2, are attached to important geologic events: to periods of folding or to the system boundaries. The corresponding data on the isotopic composition of lead were summarized and the averages for every group are shown in the table. The regular change in the isotopic composition of Pb with time or with the age of lead minerals is evident from the data in table 2. This regularity--now well known--allowed us to make the assumption that all of the $Pb^{206}$and Pb^{207} is radiogenic. By using the well-known exponential law of radioactive decay, $N_t = N_o$, it was not difficult to calculate and to construct the entire accretion curve for Pb^{206} and Pb^{207}, from the present to the time when the concentration of one of these isotopes was equal to 0, that is, to the time when the first atoms of Pb^{206} and Pb^{207} appeared or the time when radioactive decay of

TABLE 2. Average isotopic compositions of ordinary lead of various ages
(Data from Vinogradov, S. I. Zukov, I. K. Zadorozhny, K. G. Rik, Nier, Collins and others)

Epoch of folding	Age* (million years)	Isotope abundance (Pb^{204} = 1)			Number cases considered	Number anomalies not considered
		Pb^{206}	Pb^{207}	Pb^{208}		
Alpine	25-180	18.45	15.64	38.34	25	1
Variscan	200-260	18.11	15.75	38.24	19	3
Caledonian	280-400	17.17	15.46	37.00	6	1
Proterozoic	600-1200	16.48	15.39	36.00	10	3
Upper Archean	1400-2000	15.36	15.25	34.77	9	-
Lower Archean	>2000 <3000	14.10	14.91	34.05	13	-
					Total 82	8
					Grand total	90

* Absolute

uranium began. We must make still another assumption, in this connection, namely, that the proportions of U, Pb, and Th in rock remained undisturbed, except by the radioactive decay, throughout the span of time under consideration. And yet all of the lead mineral specimens were obtained from the granitic shell of the earth, where possibilities of remelting, granitization, and, consequently, of repeated parting of lead from the rock and of mixing of lead of different age most certainly cannot be excluded. Our calculations show, however, that such effects are apparently not very great. On the other hand, outstanding anomalies in the isotopic composition of lead, that is, the disharmonies between the age as indicated by geologists and the composition, are not numerous. These constitute approximately 15 percent of the total. It is of interest to note that if even the most ancient lead (for example, lead from the Rosetta mine, South Africa), the age of which is estimated on the basis of its isotopic composition as about 2.86 billion years, were a mixture of leads of different age, one of these leads must be even older, of necessity, by simple arithmetic.

Figure 1 shows accretion curves for radiogenic Pb^{206} and Pb^{207} obtained by the least-squares method applied to the experimental data an by extrapolation of the curves so derived to the hypothetical beginning of the radioactive decay of U and Th. Thus the age of the earth is approximately 5 billion years. It may be more appropriate to call this the age of terrestial substance, although this is beside the point. Apparently this figure represents the upper maximum time limit for the existence of the earth, inasmuch as we had assumed that all of Pb^{206} and Pb^{207} is radiogenic; the age would have been lower otherwise. On the other hand, we had assumed the constancy of the U:Th:Pb ratios in terrestial rock subject to change only by the radioactive process. If we had assumed redistributions in the U:Th:Pb, for example, during formation of the granitic shell, the age would have become higher. Fortunately, all such speculations are

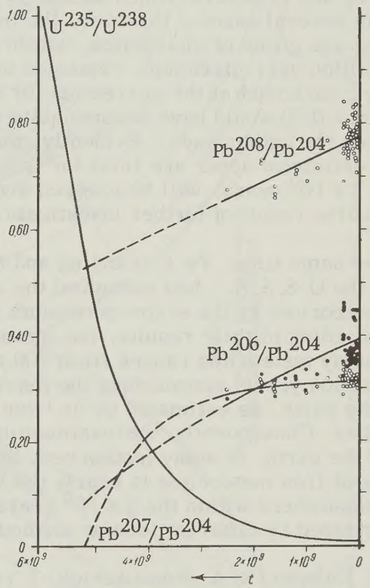


FIGURE 1. Content of lead isotopes (in relation to Pb^{204}) in time

terminated by the circumstances that a physically impossible situation would result, were the age of the earth increased beyond 5 x 10^9 years. Beginning with 4 billion years, and beyond, the content of U^{235} is increasing significantly. This increase would become catastrophic beyond 5 billion years when repeated changes in the U^{235} content would take place within an insignificantly short period of time. The amount of heat produced by the decaying U^{235} would be sufficient to vaporize the terrestial substance. The accretion curve for U^{235} is shown in figure 1.

At this time, the age of the earth may be compared possibly only with the age of meteorites. It is known that iron meteorites conserve their He^4, for all practical purposes, even when heated to 1,000°C, while stony meteorites lose their He^4 even upon a slight heating. Following the

classical helium method, Panet, in 1931, gave the first estimations of age for iron meteorites. In 1942, he reexamined his results, to some extent, and, according to his data, the age of iron meteorites ranges from several million to 6.8 billion years, with the majority having the age of 1 to 6.8 billion years.

It was discovered later that, in addition to He^4 which is formed upon decay of U and Th, meteorites contain also He^3, the isotope originating under the influence of intensive cosmic radiations, according to the reaction: $N^{14} \cdot n^0 = C^{12} \cdot H^3 \rightarrow He^3$. It was necessary to ascertain the proportion of cosmic He^3 in the helium of meteorites and to make the appropriate corrections in their age. Panet has published these data recently, in consequence of which the age of iron meteorites is now lower and is several times as low as it was before in several cases. However, the most interesting age group of meteorites, within the 1 to 6.8 billion year maximum, remained unreevaluated, inasmuch as the correction for He^3 (He^3:He^4 = 0.3) would have become quite appreciable, as the author says. Evidently, the previously estimated upper age limit for iron meteorites, 7×10^9 years, will be lowered significantly as the result of further investigations.

At the same time, Ye. K. Gerling and K. G. Rik, of the U. S. S. R., had measured the age of stony meteorites by the argon-potassium method. According to their results, the age of different stony meteorites ranges from 700 million to 4.5 billion years; approaching the maximum age of the earth, as estimated by us from the Pb isotopes. Consequently, the maximum upper age limit of the earth, of stony meteorites, and apparently of iron meteorites is nearly the same and is somewhere within the 5×10^9 years range, as determined by different isotope methods.

V. G. Khlopin, K. A. Nenadkevich, I. Ye. Starik, and others, as well as many investigators abroad, have obtained data on the age of different magmatic rocks, as the basis of the absolute geologic scale of rock age, by using the classical helium and lead methods and with attention to the present isotopic composition of Pb. New methods of determining age, by accumulations of Ar^{40} in minerals containing K or of Sr^{87} in minerals containing Rb, gave harmonious results, on the whole, although it is not possible for me to discuss this topic. Further work in this direction is being developed in the Soviet Union.

I should wish to show you some areas of the most ancient land, the age of which exceeds 2×10^9 years, as determined by the methods here enumerated. Distribution of these ancient shields composed of Proterozoic and Archean rock, together with their absolute geologic age, may be seen in figure 2. The distribution pattern produces an impression of geologic contemporaneousness of these ancient shields. However, most recently, still greater age data made their appearance in the literature, as high as 3.5×10^9 years (for Swaziland, South Africa) and caused some discussion.

These single determinations by the strontium method although possibly incorrect still attract our attention. Therefore, the lower age limit for the earth is somewhat between 5×10^9 and 2.5×10^9 years. This age is called often the age of formation of the earth's crust. It appears to me that it is closer to the upper age limit of the earth.

An erroneous view may develop in respect to possibilities of determining the absolute age in geology if we neglect to consider new isotope methods and--and this is just as important--the significantly increased time span within the limits of which it is becoming possible to obtain the age data for rock. For example, within the 500,000 year limit, the Quaternary, time may be estimated by means of ionium, a product of the decay of U^{238}. V. I. Baranov used this method in determining the age and the rate of sedimentation of the Okhotsk sea sediments and for other seas.

A remarkable view is presented to us by the age method based on the gradual disintegration of radioactive isotope C^{14} which is formed in the atmosphere under the influence of cosmic rays by the reaction $N^{14} \cdot n^0 = C^{14} \cdot H^1$. This method, enabling us to determine the absolute age within the historic time, especially from 1,000 to 25,000 years, is exceptionally important in archeology, pedology, and Quaternary geology. A large body of data is now available, by which the history of human society may be dated exactly.

The concentration of C^{14} in carbon is extremely small. At the highest (in modern carbonates), 1 gram of carbon yields 16 decays of C^{14} atoms per minute, on the average. A highly exact counting is required. There are serious difficulties in the procedures. Special counters are employed in the determination of C^{14}. The counts are continued for several days. The background is depressed severely by powerful shields of iron, compensator-counters, and other equipment. A highly involved chemical pretreatment of test materials precedes the analysis.

A "machine," an automatic counter, similar to the one in figure 3, was built at our institute by A. V. Trofimov. Trofimov has found, for example, that the remains of the mammoth from Taimyr have the age of about 12,000 years. This date is comparable to late Pleistocene in other areas. It is quite evident that the method needs wider developments.

Let us pass now from the problems of age to the problems of gases of the atmosphere. Our knowledge if the isotope composition of gases of the atmosphere, volcanos, and rocks is still entirely fragmentary. Nevertheless, the data already accumulated allow us to pose some major

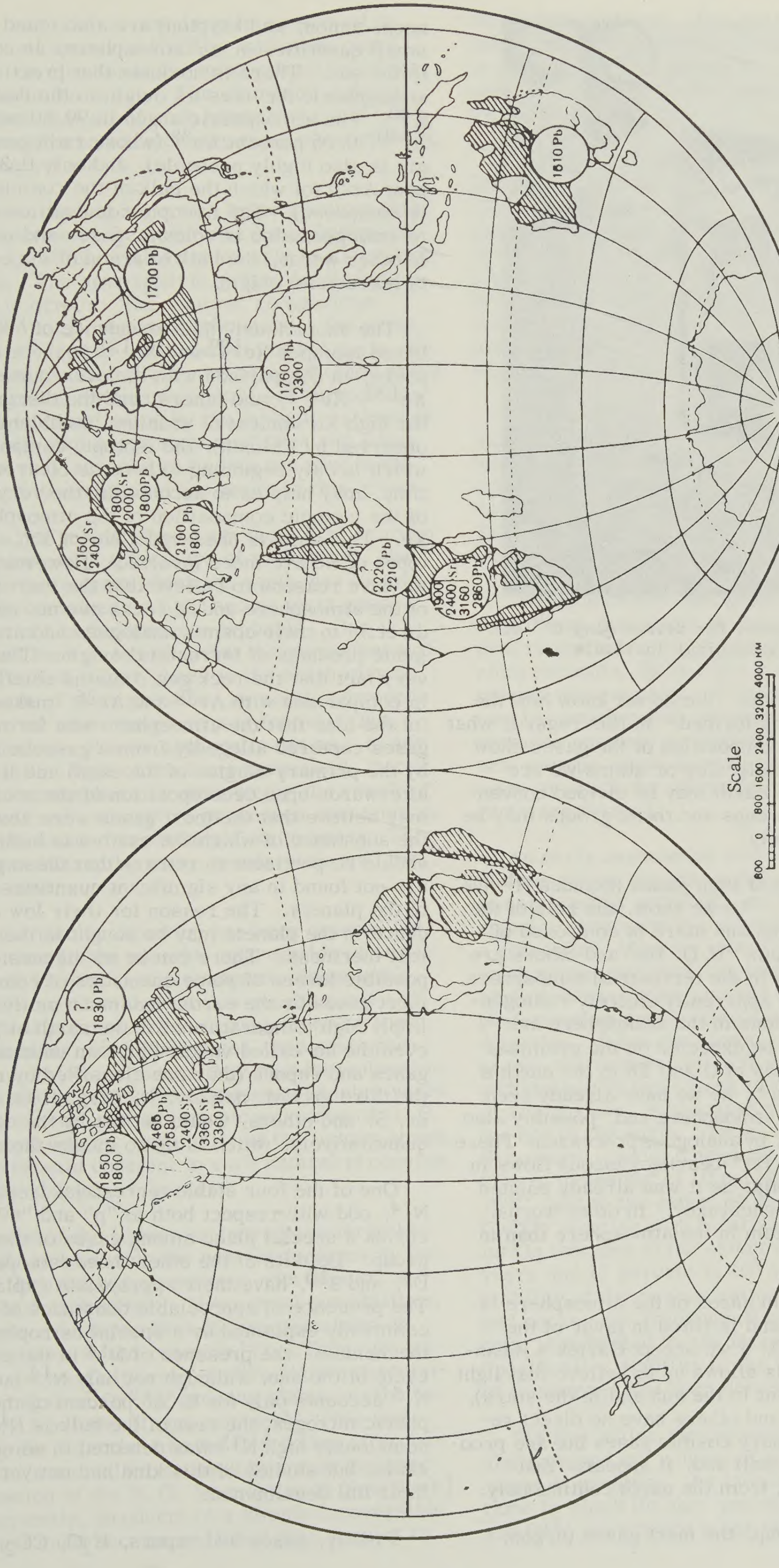


FIGURE 2. Worldwide distribution of oldest rocks and their ages (in millions of years)

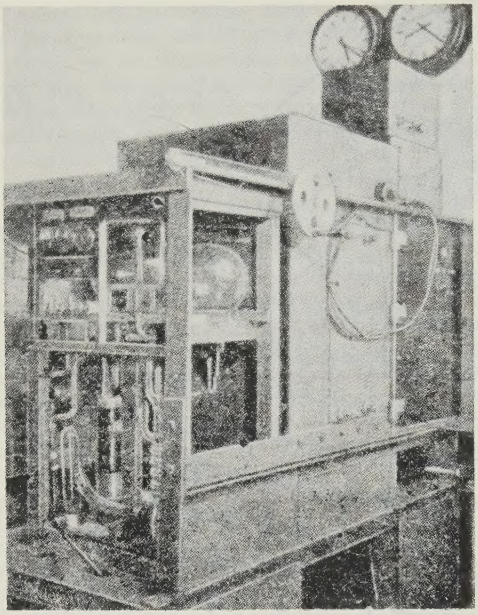


FIGURE 3. Apparatus for determining C^{14} at the Geological Institute

and general problems. We do not know how the the atmosphere was formed. In this regard, what does the isotopic composition of the gases show us? All gaseous molecules or atoms we are dealing with in the earth may be divided conveniently into three groups and these groups may be discussed separately.

The first group of light gases includes H^1, D^2, H^3, He^3, and He^4. As we know, the bulk of the substance in the sun and stars is composed of hydrogen and helium. H, D, He, and others are insignificantly low in the terrestrial atmosphere. Moreover, He^4 is apparently entirely radiogenic and its proportions in the atmosphere are lower than should be expected on the premises of the rates of decay of U and Th in the earth's crust. He^3 (and H^3), as we have already seen, are formed in the atmosphere and, possibly also in some minerals, by analogous processes. There are practically no He^4-bearing gaseous flows in terrestrial minerals, as it was already pointed out by M. G. Meshcheryakov. In other words, there is more helium in the atmosphere than in rocks.

The H/D ratio in gases of the atmosphere is in disequilibrium and is tilted in favor of the heavy hydrogen, D, if we accept Gartek's measurements. All this allows us to believe that light gases (preponderant in the sun and in the stars), H, D, He^4, He^3, and others have no direct relation to any primary cosmic gases but are products of the earth itself and, it appears that they are departing from the earth continuously.

The second group, the inert gases (argon, neon, xenon, and krypton) are also found in very small quantities in our atmosphere, as compared to the sun. There is no doubt that practically all atmospheric Ar owes its origin to the decay of K^{40}. The atmospheric argon is 99.60 percent Ar^{40}, 0.06 percent Ar^{38} (whose radiogenic origin is also highly probable), and only 0.33 percent Ar^{36} (of which the bulk of the cosmic argon is composed). The isotopic composition of argon is analogous also in volcanic gases and in rock. In other words, the bulk of argon of the earth is of terrestrial origin.

The anomalously high abundance of odd-numbered isotopes Xe^{129} and Xe^{131} in the atmosphere, in comparison with the even-numbered Xe^{130}, Xe^{128}, and others, and the discovery of the high Xe-content of uranium pitchblende (first observed by Khlopin), the isotopic composition of which is only beginning to become clearer at this time, may help us to account for the very origin of the isotopic composition of the atmospheric Xe. The same is observed also for Kr. The isotopes of Ne are more involved. However, if so, we have reasons to believe that the inert gases of the atmosphere and of rocks are not related directly to their cosmic analogues and are radiogenic products of terrestrial origin. The very fact that the rock gas contains chiefly Ar^{40}, in comparison with Ar^{38} and Ar^{36}, makes doubtful the idea that the atmosphere was formed by gases captured allegedly from a gaseous cloud by the primary magma of the earth and liberated afterwards upon decomposition of the rock. One may believe that the inert gases were absent from the substance of which the earth was built. It should be pertinent to remark that these gases are not found in any significant quantities in any of the planets. The reason for their low abundance in the planets may be sought in their chemical inertness. There can be no discussion of possible losses of some quantities of cosmogenic inert gases by the earth, inasmuch as this would imply high temperatures for the earth at which even the so-called vulgar [Tr. : an unusual usage] gases and vapors (they are classified by me as the third group), namely, N, CO_2, H_2O, O_2, Cl, Br, S, and others, would be lost by the earth quantitatively, which is by no means the case.

One of the four stable terrestrial isotopes, N^{14}, odd with respect both to "p" and "n°", occupies a special place among gases of the third group. Deficits of the other three isotopes, Li^6, D^2, and B^{10}, have their appropriate explanations. The presence of appreciable quantities of N^{14} is commonly explained by a special astrophysical mechanism--the presence of N^{14} in the carbon cycle of the sun, although not only N^{14} but also N^{15} accounts only for 0.365 percent of the atmospheric nitrogen; the rest of the bulk is N^{14}. Anomalously high N^{15} was detected in some minerals, but studies of this kind had not yet attained their full development.

Finally, gases and vapors, H_2O, CO_2, O_2, S,

Cl, Br, and others, are largely conserved in their fossil state, as $CaCO_3$, and other compounds, or else form the anionic fraction of the salt bulk in the ocean. The elemental calculations show that all of such quantities could not have been produced in consequence of weathering of ordinary rock.

We are dealing here with some peculiar planetary fraction of the substance the geochemical history of which is clear to us only in its general aspects. The atmospheric oxygen is of photosynthetic origin. The isotopic composition (C^{12}/C^{13}) of limestone carbonates is the same as that of C in the carbonic acid of volcanos. We also know the isotopic composition of other gases in this group. But, as we shall see further on, all this is complicated by the isotopic exchanges and it will take much additional time and labor until we may succeed in finding our way in the means of the origins of the gases in this group.

As a net result, the known facts lead us to an admission, with a measure of probability, that the substance from which the earth was formed directly contained no light and no inert gases, at least not in the amounts probable. One is often led back to the idea that the persistence of the so-called vulgar gases in the earth may be the result of their presence as solid compounds at the time when the earth was formed. But, nevertheless, this is apparently not so. In any case, in the light of the facts here cited, our modern atmosphere is undoubtedly the result of chemical and radioactive processes operative in the earth and is "secondary," so to speak. This view was shared by many geochemists-and for a long time.

No particular attention has been devoted for a long time to the possible segregation of stable isotopes in natural environments, despite the fact that one should think that geochemical and biological processes are distinguished by their directedness, ionic exchanges, and other phenomena, by which means they may be isolated in laboratories. Only the experience of later years had convinced us that isotopic mixtures of O, C, S, N, and others, especially of the lighter atoms, do not remain constant in such natural processes but may change $\pm$ 5 percent.

Atoms of the lighter isotopes have large kinetic advantages over the heavier isotopes by virtue of their higher accessory, vibrational, and rotational mobilities. Given equal possibilities, the lighter isotopes have higher velocities of participation in the reaction [Tr.: Thus, for example, some California studies show a discrimination against C^{14} by growing plants, to the extent of 13 percent (from memory). This was among the objections to the C^{14} dating of archeological materials discussed by me at the special session of the W. G. Foundation in New York.] Consequently, products of a simple irreversible reaction must become enriched with respect to the lighter isotopes. For example, when organic substances are oxidized, similar to when water is evaporated, the lighter isotopes are volatilized preferentially, while the heavier ones are enriched in the residue.

Parting of isotopes during mobile-equilibrium processes in natural environments is observed more frequently, however. In such cases there generally develops a disproportional distribution of isotopes between the reacting molecules, because of the differences between the rates of the forward and reverse reactions; the lower the temperature of the process, the greater the parting effect. This leads to the uniformity of the isotope distribution at elevated temperatures.

It is possible to assume even now that no significant parting of isotopes may be expected at high temperatures up to 700 to 1,000°C which are observed in silicate melts, as, for example, during the fractional crystallization of magma. This may be illustrated by the data on the distribution of O, C, and S isotopes in magmatic rock.

The equilibrium constants and the partition coefficient of isotopes in the more important natural reactions, such as $H_2O \cdot CO_2$ and its equilibrium products, $SiO_2 \cdot H_2O$, and others, were calculated theoretically. This is especially important for geochemical purposes inasmuch as it becomes possible to consider the determined natural isotope ratios as indicators of the temperatures at which the minerals or the rock in question were formed.

An early assumption was to the effect that the isotope ratios remain unchanged in geologic time, in solid bodies and rock, and that they do not respond to environmental changes. It has become a conviction, later on, that this is not so. We know processes involving isotopic exchanges with ions of natural solutions and of gases. We had performed an appreciable amount of work in this direction. It has developed also that, in certain cases, the isotope ratios in some rock is indeed undisturbed in the course of time, for all practical purposes, in the time commensurable with the age of the earth. Thus, for example, $CaCO_3$ (limestone, chalk) trades its O_2 isotopes with CO_2 to the extent of 10 percent per 10^4 years at 25°C, and to the extent of 20 percent in 10^8 years. $CaCO_3$ reacting with bicarbonate ions exchanges its O_2 isotopes to the extent of 13 percent in 10^6 years and 15 percent in 10^9 years. A practical stability of the isotope ratios in many minerals and rocks over tremendous spans of geologic time is indicated by the foregoing considerations. Specifically, stability of the temperature "record" of limestones had been demonstrated.

We live within the oxysphere. Oxygen is most abundant and the volume of space occupied by its atoms is greatest. An infinite number of reactions in which the isotopes of oxygen, O^{16}, O^{17}, and O^{18}, participate takes place in nature. In

the course of all this, a partial segregation of these isotopes is operative, especially of O^{16} and O^{18}. We know of two outstanding examples of isotopic exchanges in the H_2O-CO_2 and the H_2O-SiO_2 systems by heavy oxygen. As a result, natural waters, particularly rivers, contain the smallest quantities of O^{18}, while CO_2 and SiO_2 are the highest in their O^{18} content. Oceanic waters are but slightly "heavier" in their oxygen than river waters, because of the fractionation by evaporation and for some other reasons. Therefore, a large number of natural oxides, hydroxides of heavy metals such as Fe, Mn, Cu, and others, that are formed by reactions with H_2O have the same isotopic composition of their oxygen as the isotopic composition of the oxygen of water, as a rule.

I should wish to remind you of some developments of the isotopic composition of oxygen of the air before we could touch upon the behavior of oxygen isotopes in CO_2. Direct measurements of the isotopic composition of O_2 of the air showed that it was very close to that of CO_2, that is, the oxygen was "heavy." It seemed at the time that the problem of its photosynthetic origin was definitely solved, for "heavy" oxygen of carbonic acid seemed to be a progenitor of the heavy oxygen of the air by the photosynthetic reduction. However, this was only apparently so. We had undertaken a direct determination of the isotopic composition of photosynthetic oxygen. Water undergoes a dehydrogenation during photosynthesis and light oxygen of water and not the heavy oxygen of CO_2 becomes liberated. The latter would remain in tissues of the organisms. Indeed, the organic substance of plants contains somewhat larger amounts of O^{18}. At the same time, a new conflict had arisen. The elemental calculation had shown that the oxygen level of the atmosphere is maintained entirely by photosynthesis. Thus the light oxygen liberated in photosynthesis becomes converted somehow into the "heavy oxygen of the atmosphere.

Two views are in a conflict. According to one of them, we are dealing with the results of a preferential bonding of the light atmospheric oxygen accompanying the mineralization of organic substance.

R. V. Teis has shown, however, that the partition coefficient is small in this process and may be held accountable only for one quarter of the effect. According to the second view (Dole's), the isotopic reaction $CO_2^{18} \cdot O^{16}$ is tilted in favor of the heavier O in the stratosphere at -50°C and in the presence of ultraviolet radiation. Both of these explanations have a qualitative significance. We must await a more detailed answer. In one way or another, the photosynthetic oxygen of the atmosphere is seriously reconditioned by some natural process.

It should be reasonable to expect that CO_2 from different sources (volcanic, as well as the carbonate CO_2 - limestones, dolomites, marbles) would be high in O^{18}. Indeed, maximum quantities of O^{18} is low in the so-called vein carbonates: high-temperature calcite, and others, corresponding to the temperature of their formation. Thus a method of determining the temperature of sedimentation of limestones in sea water was devised. This paleothermometric method has shown that temperatures of water in ancient seas resemble modern conditions. One may think that in the future this method may permit us to ascertain the character of extinct sea currents (by the bottom sediments), and, hence, the areal paleoclimatic conditions.

It developed further that minerals--the oxides resulting from reactions with CO_2--have the same isotopic oxygen composition as the oxygen of CO_2. This applies, first of all, to magnetites and to other skarn minerals, as our Ye. I. Dontsova has demonstrated (table 3).

Table 3. Ratio of O^{16}/O^{18} in iron, chromium, and copper minerals as percent accretion of O^{18} (according to data from Vinogradov, Dontsova, and Dole)

Material and Source	O^{16}/O^{18}*
Cuprite	
Nizhny Tagil	0
Red copper ore	
U. S. A.	+0.45
Brown ironstone	
Central Urals, Sysertsky	0
Central Urals, Sysertsky	+0.36
Central Urals, Sysertsky	0
Iron ore	
U. S. A.	+0.54
U. S. A.	+0.72
U. S. A.	-0.45
Hydrogoethite	
Central Urals, Palevak	0
Alapayevsk	-0.23
Chromite	
Aktyubinsk	+1.10
Contact iron ore	
U. S. A.	+1.6
U. S. A.	+2.0
Magnetite	
Mt. Blagodat	+2.7
Mt. Blagodat	+2.4
Mt. Blagodat	+2.5
Mt. Blagodat	+2.7
Maritime area [Tr. : Far East?]	+1.95
Magnitogorsk	+2.31
Dashkesan	+1.95
Northern Urals,	
Bayanovka	+2.31
Auerbakhsk	+2.59
Pokrovskoye	+2.22
1st North mine	+2.22
2nd North mine	+1.82
3rd North mine	+2.95

*Parameter does not harmonize with "percent in table title--Tr.

Diatomite, low-temperature quartz, and other minerals all contain increased proportions of O^{18}. For these reasons, sedimentary rocks contain more O^{18} than magmatic rocks, as it may be evident from figure 4. At the same time the more silica is present in a sedimentary rock, the higher is its O^{18} content. In brief, sedimentary rocks differ from magmatic rocks by the isotopic composition of their oxygen, in consequence of the effects of O^{18} rich molecules of SiO_2, CO_2, and others on the sediments. In the case of magmatic rocks, the O^{16}/O^{18} or the accretion of O^{18} corresponds to the isotopic composition of oceanic water. The low probability of the segregation of O_2 isotopes in magmatic rocks was already discussed. These materials occupy intermediate positions, with respect to their O^{16}/O^{18} among the other geologic materials.

Distribution of C^{12} and C^{13} isotopes in different minerals and rocks has many features in common [Tr.: with the oxygen isotopes], including even an accumulation of C^{13} in carbonate rocks, parallel with the accumulation of O^{18}. Two geochemical processes leading to a segregation of carbon isotopes in some natural materials are clearly suggested in the C^{12}/C^{13} isotopic exchanges. The first one is the photosynthesis resulting in the development of preferential uptake and bonding of the light C^{12} isotope by the organic substance and its impoverishment with respect to the heavier C^{13}. This, in turn, becomes responsible for the mineral amounts of C^{13} in all substances that are related genetically to the organic world: coals, liquid, and solid bitumens. The second process is directly opposite to the first one. It is the accumulation of C^{13} in carbonic acid of diverse origins and in its compounds: limestones, dolomites, and many others.

The noticeable differences within the isotopic composition of carbon in organic substances--tissues of organisms, coals, bitumens--and carbon in carbonate rocks have led to a rather risky attempt to establish their organic or inorganic origin on the basis of certain remnants of the so-called Corycium enigmaticum in the oldest Archean rock of Finland. The well-known obstacle here was the proximity of the C^{12}/C^{13} of organic substance to the C^{12}/C^{13} of magmatic rock, as we shall now see.

On the other hand, the problem of origin of

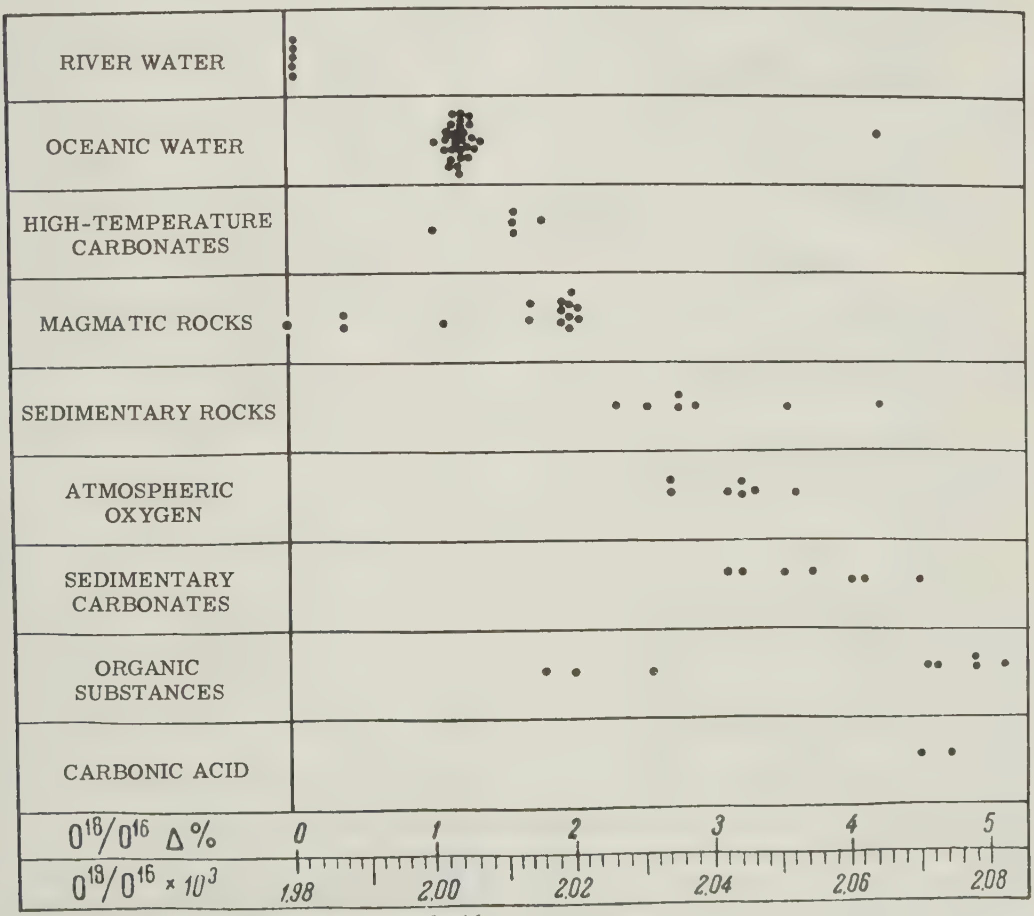


FIGURE 4. Ratio of $0^{18}/0^{16}$ in different geologic materials

graphites was actively raised. The C^{12}/C^{13} ratio is rather widely scattered for different graphites, as is shown in figure 5, and is representative substantially of the entire range of variations observed in nature. After more detailed studies of different graphites by many investigators, it has developed, for example, that the Ceylon vein graphite, found in association with pegmatites in intrusive areas must be classified with the group which is related genetically to CO_2 or $CaCO_3$. Graphites found either as inclusions in shales and in other sedimentary rocks or clearly transitional in the direction of coal were found to retain the C^{12}/C^{13} ratio close to the C^{12}/C^{13} of organic substances. Obviously, there exist two groups of graphites and the geologists who were in favor of both kinds of origin of graphites in nature proved to be correct in their view.

Incidentally, C^{12}/C^{13} in diamonds corresponds to C^{12}/C^{13} of carbonic acid. The corresponding equilibrium temperature of the formation of diamonds should be calculable, in all probability.

Magmatic rocks occupy the central position [Tr.: in their isotopic composition of carbon], even as they do in the instance of their oxygen. It was shown by Trofimov that these rocks and iron and stony meteorites have either an identical or a very close isotopic composition of carbon with a very low C^{13} content. It developed further that the least amounts of C^{13} are found in basic and ultrabasic rock as well as in stony metorites. Granites contain C^{13} within the same range of magnitudes, with a tendency toward larger amounts. Sedimentary rocks belong to different groups containing much more C^{13} than is found in magmatic rocks. It is of interest that such

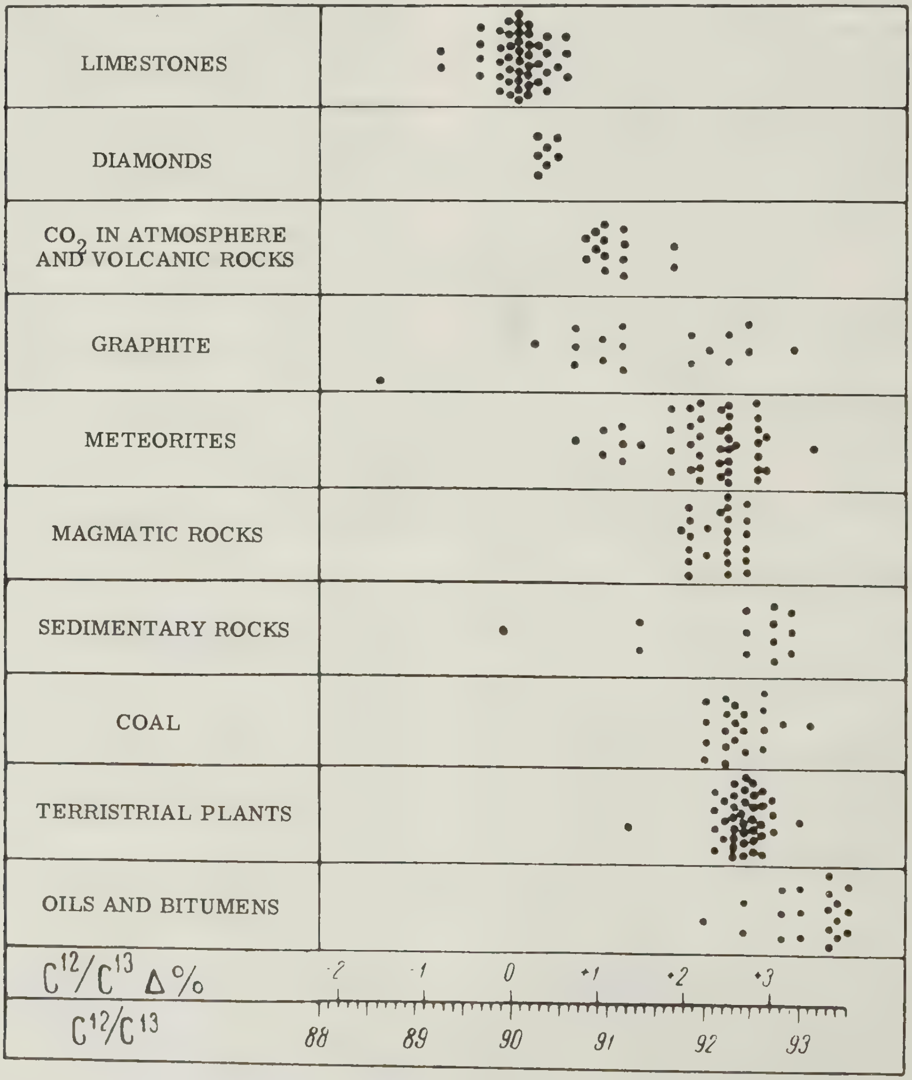


FIGURE 5. The ratio of C^{12}/C^{13} in different geologic materials

TABLE 4. Ratio of C^{12}/C^{13} in magmatic rocks and meteorites (according to A. V. Trofimov)

Magmatic rocks	
Andesite, Kamchatka	92.2
Gabbro-norite, northern Urals	92.4
Gabbro-norite, northern Urals	91.9
Basalt, Kazbeck	92.0
Basalt, Aragats	92.5
Basalt, Kamchatka	92.3
Basalt, Kamchatka	92.4
Basalt, Primorye	91.6
Syenite, Armenia	91.9
Granite, Leznyaki	92.4
Granite, Yemelyanovka	92.3
Granite, Kuznechnoye	91.8
Granite gneiss, Sartovala	91.9
Porphyrite, Namangan	91.2
Porphyrite, Primorye	91.4
Stony meteorites	
Staropesyanoye	91.2
Petropavlovka	91.3
Berdyansk	92.2
Bolshaya Korta	92.0
Sevryukovo	91.9
Stavropol	91.9
Kainsass	91.9
Grozny	91.6
Cold Bokkeveld	91.9
Novyy Uren	92.2
Migei	92.2
Staroboriskino	91.2
Pavlovka	92.2
Pervomaysky	91.9
Velikodolinskoye	92.1
Krasny Ugol	91.9
Kunashak	92.5
Okhansk	91.9
Zhovtnevy khutor	92.5
Demina	92.2
Savchinskoye	90.9
Kuznetsovo	91.9
Saratov	91.6
Borodino	92.2
Kashin	92.1
Timorkhina	92.2
Iron meteorites	
Abakan	92.2
Sikhote-Alin mountains	91.1
Dorofeyevka	91.7
Niro	90.9
Nikolayevsky	91.7
Boguslavka	91.2
Lipovsky khutor	92.8
Ilinskaya sta.	92.5
Bragin	93.1
Avgustinovka	92.5
Pallas iron	91.9
Chinge	91.9
Chebarkul	92.2

rocks as porphyrites, for which possibilities of contacts with sedimentary rocks cannot be excluded, have a higher C^{13} content accordingly (table 4).

The prevailing C^{12}/C^{13} ratio is about 92.1 and is representative of basic magmatic rock. All other variations in the C^{12}/C^{13} ratio have their origins among rocks and minerals within the zone of hypergenesis, in the biosphere, as we have already seen.

As in the case of carbon, we observe two different directions of the isotope-sorting processes; also in the case of S^{32}, S^{33}, S^{34}, and S^{36}, sulfur leading to an impoverishment with respect either to the light or to the heavy isotope in their extremes. The S^{32}/S^{34} is important to us inasmuch as the relative abundance of S^{33} and S^{36} is very low.

The smallest of "heavy" S^{34} are found in organic substances: tissues of organisms, proteins, liquid and solid bitumens, native sulfur of organic origin, and H_2S. This effect is associated with the biologic reduction of sulfate sulfur by microorganisms and to the assimilation of sulfur by higher organisms. Direct experiments with reduction of sulfates by bacteria had shown a loss of S^{34} amounting to several percent. Consequently, the cycle of sulfur transformations in nature, in the direction: $SO_4 \rightarrow H_2S \rightarrow S$ leads to an impoverishment of the endproducts with respect to S^{34}. A process of this kind is taking place, for example, within the water mass of the Black sea and of other marine basins enveloped by hydrogen sulfide fermentation. As the result, the sulfate S of sea water becomes enriched by S^{34} and the elemental S becomes lower in S^{34}. Both of them differ, in this respect, from magmatogenic (or, better, hydrothermal) sulfides, as we shall see later on.

The S^{32}/S^{34} ratio in sedimentary sulfides (as well as in sulfates) is undergoing a regular change with time, but this dependence is terminated when the sediment reaches the age of 700 to 800 million years, according to Todd's observations.

What kind of a limit is this--the lower level of the geological preservation of the S^{32}/S^{34} isotopic proportions in sedimentary rock--or is this the time when there was no SO_4 reduction on the earth?

On the other hand, we find marine sulfates, gypsum, and other compounds with the maximum content of S^{34}. The difference between the two groups may be as high as 16 percent in their content of the heavy isotope of sulfur. Finally, the intermediate position, with respect to S^{32}/S^{34}, is occupied by the sulfur of hydrothermal sulfides (pyrites, galena), as well as by sulfur of stony and iron meteorites which we have already investigated, in its proper time. Volcanic sulfur borders on sulfide sulfur and it differs accordingly from organic sulfur in its isotopic composition. For example, S^{32}/S^{34} in sulfur of Klyuchevskaya sopka is 21.9 as against S^{32}/S^{34} of 23.0 in organic sulfur. Volcanic sulfur borders on magmatic sulfur at the other end, as it may

be seen in figure 6.

The isotopic composition of sulfur in magmatic rock, hydrothermal sulfides, and volcanos is practically identical, with very small variations, as these materials constitute a single genetic group. Investigation of these very small variations in the isotopic composition of sulfur present a major geologic interest. It offers a hope for us of coming closer to the ore-forming process (by way of the isotope analysis, for example, of PbS in rock and ore), possibly even of answer to the question: was the metal derived from the rock or was it introduced into the rock? It is noteworthy that volcanic sulfur (as well as the sulfur of hydrothermal sulfides) differs from sulfate sulfur (of marine salts) in its isotopic composition.

It should be careless of us to tie the origin of volcanic sulfur to marine sulfates, especially since volcanic sulfur is accompanied by selenium. Studies of volcanic sulfur may shed some light on the still unknown region of its origin.

In summary, as the result of various radioactive processes in the earth, its chemical isotopic composition is continuously changing; this becomes especially noticeable on the geologic time scales. The isotopic exchange reactions, involving particularly the lighter atoms, are intensive in the outer shell of the earth, notably in the biosphere, and they are responsible for local enrichments and impoverishments with respect to this or that isotope. The living substance--the sum total of organisms inhabiting the earth--plays an exceptionally important role, as we have seen, in the segregation of the isotopes of oxygen, carbon, sulfur, and hydrogen.

All these isotopic changes in rocks, minerals, and organic substances place a superb instrument into the investigator's hands, on the foundation of physico-chemical laws, to help advance his comprehension of the long-past major and minor geologic events. Genesis of rocks and minerals, geologic time since the event, temperature of the process, and so forth, become illumined by a new light of knowledge with the aid of the new method. We may hope that the method may help definitely to introduce two new parameters into the geologic routine in every exact scientific investigation: time and temperature of natural processes, and that the geologist may forego his conventional "earlier" and "later" at some time in the future, as well as his "high-temperature" and "low-temperature" and will make use of the clocks and the thermometer offered to him by nature.

Studies of behavior of isotopes in natural processes are becoming broader every year. I should wish to show you, in this communication, also the extent of work performed in this field by many of our Soviet scientists. It appears to us that we must continue further to develop our scientific traditions in this field, while improving the research techniques at our institutes and making this technique accessible and extended widely in its use.

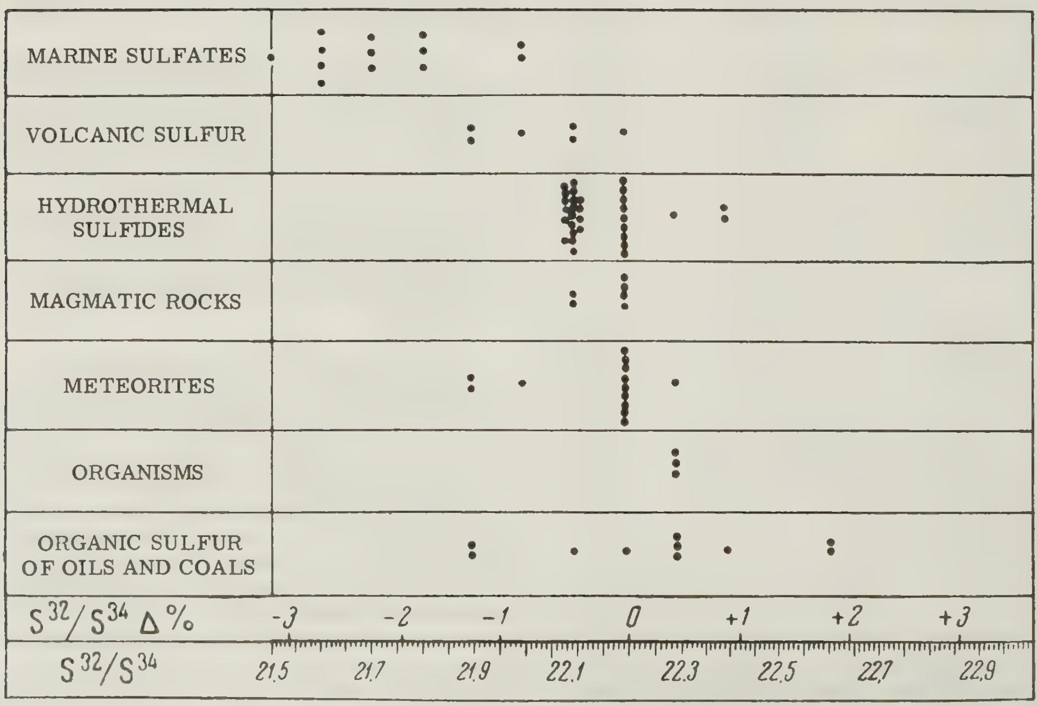


FIGURE 6. The ratio of S^{32}/S^{34} in different geologic materials

I have tried, to the measure of my capacity, within the available time, to report the state of isotope chemistry in this brief communication and have attempted to make certain generalizations. It is not up to me to judge how successful was the attempt. It was necessary for me to avoid excessive refinements - of the kind that compose the very soul substance of every investigator - so as not to make my presentation too narrow. I was counting chiefly on the geologists. It seems that I have said nothing unpleasant to them.

THE QUATERNARY PERIOD IN MANCHURIA[1]

by

Tokio Shikama

• *translated by Riuji Endō* •

ABSTRACT

The Quaternary system of Manchuria is composed, generally speaking, of three facies: the north China loess, the Mongolian eolian, and the Manchurian flood-plain lacustrine. A piedmont facies is developed in the mountain district, and basaltic plateaus are also extensively distributed.

The complete formation of the Hei-liao divide was in the Lao-ho stage (chronologically between the Ma-lan stage of the upper Diluvium and the black-earth stage of the Alluvium). Its slow upheaval may correspond with terrace movements of Du_1 plane in the islands of Japan. It is also related to the tilting movement of the Korean peninsula.

The Ku-hsiang-t'un formation is rich in fossils, including plants, mollusks, insects, fish, reptiles, birds, mammals, and others. Culture of stone implements of the Ku-hsiang-t'un formation is Mousterian to Magdalenian. Three human skulls (the Djalainor man) were found.

Some relationship may exist between the permanently frozen sediments of the Ta-hsing-an-ling Shan Mo and the Würm glacial stage of Europe or the Wisconsin glacial stage of North America. -- G. E. Denegar.

INTRODUCTION

The study of Quaternary geology in Manchuria has not progressed as far as that of the pre-Tertiary, especially in stratigraphy. The stratigraphic order of the stages is unknown. It is noteworthy that the majority of Japanese geologists[USGS Ed. : who worked in Manchuria] were hired for surveys of ore deposits, and many geologic surveys were done. In reading these reports, it will be noticed that their major interest was in "hard-rock" geology and the problems of the Quaternary system were treated very simply. The drift geology was mainly concerned with loess deposits and, it seems to me that, even the drift of the upper half of the Tertiary formation was treated as lightly as the Quaternary system. Under such conditions, the following studies are noticeably outstanding works: studies of the Quaternary volcanos in northeastern Manchuria, studies of topographic planes in Jehol and Liao-tung, studies of the sand dunes and lake deposits in Mongolia, and studies of fossil beds especially in the areas near Ku-hsiang-t'un [near Ha-erh-pin or Harbin] and Djalainor [Hu-lun Ch'in or Dalay Nor]. Though the special surveys of placer gold and diatom earth and peat, as well as surveys of ground water and dams, are, naturally, concerned with the Quaternary period, it is not treated in detail in their surveys. At the present time, it is too early to summarize the above-mentioned studies. Lately, the study of the Quaternary period has progressed remarkably in China proper (north and central China) in contrast to the studies in Manchuria which are still in a condition of preliminary work.

In 1930, Licent and Teilhard de Chardin [17] established the stratigraphy of the Quaternary system at Ou Tao Chuan, southwest of Ch'ang-ch'un and at Djalainor in northwestern Manchuria. Since then no successive studies have appeared. However, the former developed into a chronological study of the vicinity of Ch'ang-ch'un by Sōki Yamamoto [41] in 1948, while the latter developed into the discovery and the study of the human skeleton at Djalainor by Riuji Endō [6] in 1944. The Quaternary system in Jehol, which is adjacent to north China, has been studied more than in other districts of Manchuria. Following the geomorphologic studies by Barbour [4] in 1935, Fumio Tada [32] published studies in the same line in 1937 based on his work with the First Scientific Expedition to Manchuria and Mongolia. The geomorphologic and stratigraphic studies in the vicinity of Pei-piao by Shigeru Kusamitsu [16] in 1942 further advanced knowledge of the Quaternary geology of Jehol. Knowl-

---

[1]Translated from Geology and Mineral Resources of the Far East, Manchuria, pt. III, Stratigraphy: published under the auspices of the Compilation Committee of Geology and Mineral Resources of the Far East, 1951; translation prepared for the Office of the Engineer, Headquarters, United States Army, Japan; edited by Phyllis Foreman, U.S. Geological Survey.

This translation contains illustrations which did not appear in the original publication. Place names were checked insofar as possible with Board on Geographic Names gazetteers. A useful adjunct to this translation is the Army Map Service Road Map of Manchuria, L201, scale 1:2,000,000.

edge of the Quaternary system in Liao-tung was accumulated by Japanese geologists for a long time but resulted in comparatively few publications. The most important, concerned with the excavations at Ku-hsiang-t'un, Harbin, which was done as a part of the First Scientific Expedition to Manchuria and Mongolia, are by Shigeyasu Tokunaga and Nobuo Naora [36, 37, and 38] . They reported many fossils and human relics. However, their studies were based on pioneer work by Russian scholars, such Loukashkin and Ponosoff [25]. Stratigraphic knowledge was further clarified by the excavations of the Central National Museum of Manchoukuo [5 and 28], in 1927-28. Paleontological and chronological study of the materials excavated by the Manchoukuo Museum were delayed or prevented as all of the material was scattered and lost due to the war.

CHARACTERISTIC FEATURES OF THE QUATERNARY SYSTEM IN MANCHURIA

Rinji Saito [27] divided the sedimentary facies in Manchuria into the south Manchurian type and the north Manchurian type and drew a line which connects Wu-tan-ch'eng, K'ai-yüan, Hui-nan, An-t'u, Mo-zan [Musan], and Seishin [Ch'ongjin] (approximately the 43° parallel of north latitude) as a boundary line; this is named the Hui-nan-K'ai-yüan line. The Tertiary system located on the north side of this line represents the Siberian facies, while that on the south side has close relations to the north Chinese facies. However, the Hua-tien series, like the Feng-shan series, shows a transitional facies between the Siberian-north Japanese side and the north Chinese side. Therefore, it may not be possible to divide the system into two distinct areas. Teilhard de Chardin [34] divided the Quaternary sedimentary facies into three large divisions: the north Chinese facies, the Manchurian facies, and the Mongolian facies. The north Chinese facies do not appear much beyond the Kwei-nan [Hui-nan]-K'ai-yüan line. Jehol belongs, on the whole, to the north Chinese facies, while the western slope of the Ta-hsing-an-ling Shan Mo belongs clearly to the Mongolian facies. Although the Manchurian plain looks like a prolongation of the plains of north China, it is characterized by the Manchurian facies. The north Chinese facies and the Manchurian facies are bounded not by a line which runs east-west, but by a line which runs approximately north-northeast—south-southeast [USGS Ed. : A line connecting Cheng-chia-t'un and K'ai-yüan would bear north-north-west—south-southeast.] , a line which connects Cheng-chia-t'un [Liao-yüan] with K'ai-yüan. The fluvio-lacustrine facies, which is most characteristic in the Manchurian facies, develops mainly along the Sung-hua Chiang [Sungari river] (upstream from Kiamusze [Chia-mu-ssu]) and from Pei-an in the north to the eastern foot of the Ta-hsing-an-ling Shan Mo and south to the area including Ch'ang-ch'un and Sze-ping-kai [Ssu-p'ling-shih]. Its eastern limit is distinctly bounded by a line which connects Chi-lin with I-t'ung. In the area east of this line, piedmont facies such as terrace deposits, talus, and fans developed along each river, though on a small scale. These piedmont facies gradually pass into the above-mentioned fluvio-lacustrine facies. Roughly speaking, the loesslike deposits in Kamisambo [Sangsambong] district along the To-men Chiang [Tumen river] near Lung-ching-chieh, Yen-chi Hsien, Kien-tao [Chien-tao] province is a prolongation of the Manchurian facies. The type of the Manchurian facies is the Ku-hsiang-t'un formation which consists of loess, sand, and loam. The formation contains abundant fossils; in this respect the Manchurian facies is different from the north Chinese facies.

If the type of north Chinese facies in Manchuria is represented by the Liao Ho plain group, it may be rather preferable that the drifts which are developed along the Lao-ha Ho, particularly in the vicinity of Ch'ih-feng, are selected as the type, although this is slightly different from the view of the original author. The coastal district of Liao-hsi [USGS Ed. : Liao-hsi is the area west of the lower Liao Ho.] clearly belongs to the north Chinese facies. The facies of the Liao-tung peninsula are questionable, however, they probably belong to the north Chinese facies in a broad sense.

Basaltic plateaus occupy a vast area in north-eastern Manchuria. The detailed eruptive stages of the basalts and the relation between them and the Ku-hsiang-t'un formation have not yet been determined. The relation between the rock detritus formation of the Ta-hsing-an-ling Shan Mo and the Djalainor formation or the Ku-hsiang-t'un formation is also unknown. However, the relation between the glacial stages of P'ai-t'ou Shan and its volcanic activity, reported by Gorō Asano [2], may give some assistance to the present problem.

CHRONOLOGY

The formations ranging from the Pontian in the lower Pliocene to the Alluvium (H-K) were divided into six units, Jehol - Liao-hsi, Ta-shih-ch'iao, Liao-tung peninsula, the coast of the Yellow sea , Shen-yang, the Sung-hua Chaing districts, and they were correlated as shown in table 1 [29]. Inner Mongolia, the mountain district of eastern Manchuria, and the marginal part of Korea are omitted as the Diluvium in these districts has not yet been studied. [As much as they offer the data for its chronological works.] In table 1, the general horizons recognized in north China are shown, and the horizons of of Manchuria were correlated with those of north China. Erosion stages A-G are based on Teilhard de Chardin's classification and 1-4 are noticeable deposition stages.

Among the four deposition stages in north China

TABLE 1. Correlation of the younger

	General succession of N. China	Luan Ho (Tada)	Ta-ling Ho (Tada)	Jehol (Tada)	Jehol—Liao-hsi
K_2	Pan-chiao stage (G)	-	30-40 m terrace (Endō, Morite)	-	Present erosion
K_1	Black-earth stage	-	-	-	Black-earth stage
J_3	(4) Ma-lan stage: Djalasogor sand bed	-	First denudated plane 60-120 m	First denudated plane Chang-tu plain 60-120 m	Erosion of Lao-ha stage
J_2	(4) Ma-lan stage: Djalasogor sand bed —(F)— Ma-lan loess	Loess	Loess	Loess	Ch'ih-feng stage: Redeposited loess (partially gravel bed) Erosion Liao-ho stage Jehol loess
J_1	Ching-shui stage (E)	200 m a Denudated plane	Second denudated plane 180-200 m	Second denudated plane Tung-liao plain 180-200 m	Erosion
	Chou-k'ou-tien stage (3)	-	-	-	Loam Reddish clay group
I_2	Huang-shui stage (D)	280 m b Denudated plane	Third denudated plane Chahtara plain 280-300 m	Third denudated plane 280 m	Erosion of Ta-ling-ho stage
I_1	San-men stage (2)	-	-	-	
H	Fen-ho stage (C)	400 m c Denudated plane	Fourth denudated plane 400-420 m	Fourth denudated plane Chahatam plain 400-420 m	-
	Pao-te stage (B) (1)	480 m d Denudated plane	460-490 m	460 m	Pei-piao red-earth bed / Ling-yuän red-earth bed
G	Tang-hsien stage (A)	560 m e Denudated plane	Fifth denudated plane Kien-ping plain + 540 m	Fifth denudated plane 560 m	-

namely, the Pao-te, San-men, Chou-k'ou-tien and Ma-lan, the Ma-lan and Chou-k'ou-tien belong to the Diluvium. In Manchuria, the Ma-lan stage is most extensively developed, while the Chou-k'ou-tien series is distributed sporadically. The occurrence of the San-men series in Manchuria is not confirmed, while the Pao-te series is found in Jehol province and the Liao-tung peninsula alone.

Based on observation of deposits of the later Cenozoic era distributed between Ch'ang-ch'un and Pai-ch'eng-tzu [T'ao-an] and between Ssy-p'ing-shih and Cheng-chia-t'un, Yamamoto [41] divided it into seven sedimentary stages, in ascending order, as follows:

Gravel	(Tang-hsien stage)
Red sand and clay	(Pao-te stage)
Sand	(Fen-ho stage)
Bluish-gray clay	(San-men stage)
Gravel	(Ching-shui stage)
Brown clay	(Ma-lan stage)
Sandy clay	(Pan-chiao stage)

He also pointed out three remarkable features as follows: 1) the clay in the Pao-te and

Cenozoic system in Manchuria

Vicinity of Ta-shih-ch'iao	Liao-tung peninsula	Coast of the Yellow sea	Chang-chun - Shen-yang	Shun-hua-chiang, Harbin
Forming of present small valleys	Forming of present small valleys Slight upheaval	Forming of upheaved coast Muddy coast	Erosion of the present time	Erosion of Shun-hua-chiang stage
-	Submergence of Ta-lien bay Black earth Pu-lan-tien stage	Ta-ku-shan peat bed Redeposited clay bed	Black-earth stage	Wen-chuan-ho bed (Wen-chuan-ho stage)
-	Pi-tzu-wo stage (period) 20-50 m	Upheaval Erosion	Upheaval Erosion	Erosion of Wapen-yao stage
Kai-ping clay group (Elephant of Pei-piao)	Pu-lan-tien clay group Base of Pi-tzu-wo plane (Ta-lein mammoth)	Ta-yang-ho yellow-clay bed	Liao-ho plain group (mammoth) Hun-ho clay bed Yin-cheng-tzu gravel-clay Chang-chun clay bed	Upper Ku-hsiang-t'un formation Lower
Erosion and upheaval More than 30 m was dissected	Kuang-ning-ssu plane 120-200 m Liao-tung peneplain	Erosion of Liao-tung stage	Erosion of bed rock Effusion of basalt	
Hsiao-sheng-shui-ssu group Niu-hsin-shan group	Reddish clay	-	Chang-tu fissure bed (Red formation)	
Forming of caves and fissures	-		Forming of cave and fissures	
-	-	-	Sand	
	Chin-chou clay group	Chuang-ho red-clay bed	Red sand and clay	
	-	-	Gravel and sand	

San-men stages are not reddish in general, 2) the development of sand in the Fen-ho stage is poor, and 3) a downwarping occurred prior to the Ma-lan stage. Yamamoto's division has not been confirmed from the paleontologic point of view. His division is unique in that he applied a deposition stage to each erosion stage of Tang-hsien, Fen-ho, Ching-shui, and Pan-chiao.

At any rate, it is certain that level planes, such as erosion or denuded planes, are very important in the choronology of the Quaternary period. Studies of this line have not progressed to an extent that the level planes in all of Manchuria can be correlated. There are piedmont plains developed in a position lower than the so-called Mongolian peneplain or Pei-tai peneplain, for example, the hilly plain at Fu-lung-chüan and the erosion planes of sand and gravel underlying the loess belong to the piedmont plain.

The erosion of the Ching-shui stage is generally found in Manchuria, for example, the erosion of the Liao-tung peneplain corresponds with this stage. The Kuang-ning-ssu plane

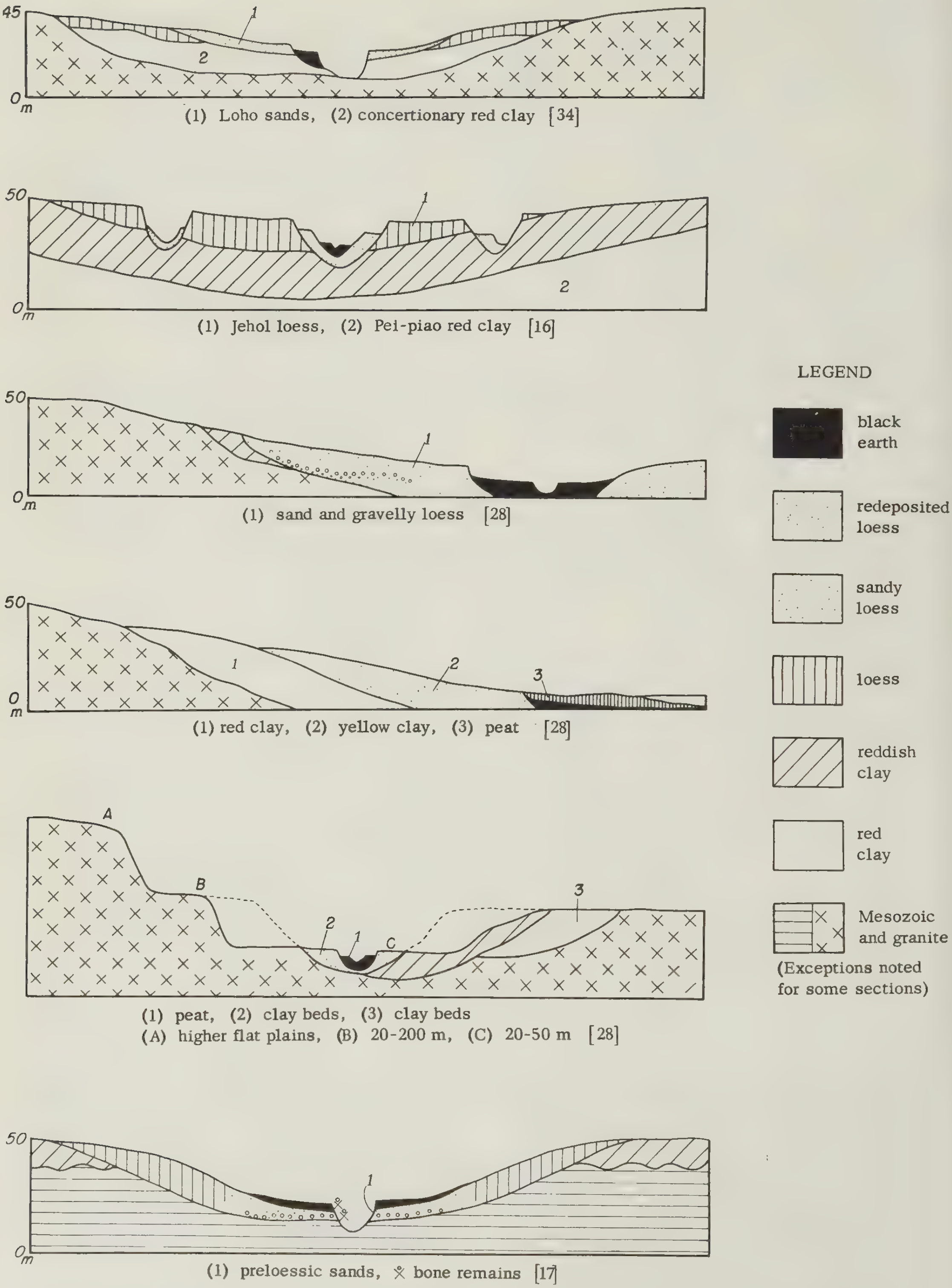


FIGURE 1. Diagrammatic sections of Quaternary sediments in Manchuria

(120-200 m), which was studied by Zenkyō Imamura and Teijirō Tsuchida [13], and many other high-level planes are cut directly into the basal rock. In some parts, the planes coincide with the deposition planes of the Pu-lan-tien clay group or the Kai-p'ing clay group in the valley bottoms. However, considering the plane of [unconformity] between the Pu-lan-tien clay and the reddish-clay formation may correlate with the Kuang-ning-ssu plane, the author [29] correlated the erosion of the Liao-tung peneplain with the Ching-shui stage. The erosion stage of Ta-ling Ho which makes the unconformity between the Pei-piao red-earth bed and reddish-clay formation may correspond to the Huang-shui stage. The Fen-ho stage is not common in Manchuria. In the post-Ma-lan stage, since the sedimentary facies in Manchuria are well developed as compared with that of north China, it is possible to study in detail the erosion stages in the post-Huang-shui stage.

In a certain sense, the division of the level planes of Jehol by Tada is contrary to Yamamoto's views. In contrast with Yamamoto, Tada divided the denudation stages only leaving the relations between the denudation stages and the deposition stages unknown [32]. Tada distinguished about six horizons of denuded planes in Luan Ho, Lao-ha Ho, and Ta-ling Ho districts and he correlated them with those of north China. It seems to me that Tada owes his classification to the developmental history of the topography at Szechingtao, in Chih-feng district, which was studied by Barbour. The writer correlated the chronology in Manchuria with the new chronology in north China and revised the correlation table. The present erosion in the post-Lao-ha erosion stage was named with Ling-ho stage by Barbour. However, since it is liable to be confused with Teilhard de Chardin's Ling-ho stage and it is also not so important, the writer wants to avoid the use of Barbour's Ling-ho stage in this paper. Babour's loam formation in Tada's correlation was correlated not to the San-men series, but to the Chou-k'ou-tien series. The Ta-ling Ho erosion stage was merely an erosion stage between the red-earth stage and the loam stage, and it is as yet unknown if it can be correlated with the erosion stage between Huangshui and Fen-Ho or that between Pao-te and Yu-she. At any rate, the denuded plane which Tada divided in Jehol developed in three states in the region ranging from the Kien-ping [Chien-ping] plane to the T'ung-liao plane.

In Pei-piao district, the presence of reddish-clay formation between the red earth and the loess was pointed out by Kusamitsu and the number of erosion planes increased.

The Ching-shui, or the Liao-tung, erosion stage is very important as it divides the Diluvium in two, upper and lower; thus the confirmation of this stage will be most important for the chronology of the Diluvium in Manchuria.

TABLE 2. Correlation of erosion planes in North China and Manchuria

North China	Manchuria
a. Tang-hsien stage erosion (foundation of Pao-te series)	Kien-ping plane, fifth denuded plane Fu-lung-chuan plane Rop-pyaku-zan plane
b. Erosion between the Pao-te and Yu-she series	Denuded plane, d
c. Fen-ho stage erosion (between Yu-she and San-men)	Chahatam plane, fourth denuded plane
d. Huangshui stage erosion (between Chou-k'ou-tien and Ma-lan)	Liao-tung stage erosion (Chatara plane, third denuded plane)
e. Ching-shui stage erosion (between Chou-k'ou-tien and Ma-lan)	Liao-tung stage erosion (Tung-liao plane, second denuded planes, Kuang-ning-ssu plane)
f. Liao-ho stage erosion (between Ma-lan loess and Djalasogor sand bed)	Erosion between loess and redeposited loess, Wo-pen-yao stage erosion (Chang-tu plane, first denuded plane)
g. Pan-chiao stage erosion (erosion of the present time)	Sung-hua-chiang stage erosion

HSIAO-SHENG-SHUI-SSU GROUP AND NIU-HSIN-SHAN GROUP

In 1942, the presence of cave deposits in the magnesite quarry at Ta-shih-ch'iao was brought to light. In the same year, Mitsuo Noda [22] did field work at this place, and in 1943 the writer and Kusamitsu visited there and collected many fossils. There is a fissurelike cave (25 meters (m) in length and 5 to 10 m in width) on the slope of a hill, 60 m in relative height and 130 m above sea level, at the magnesite quarry of Hsiao-sheng-shui-ssu. The deposits in the cave consist of a white-sand bed (lower part) and a reddish-brown residual-clay bed (upper part). The residual clay filled up small fissures and the depressions which are found in the Karrenfeld in the upper part of the quarry. The hill of Hsiao-sheng-shui-ssu itself is a kind of monadnock. Therefore, it seems to me that the formation of residual clay accompanied the erosion of the monadnock. Consequently, it seems to be older than the Kai-p'ing clay group which is distributed extensively from the foot of the hill to the valley bottoms. The writer wants to name this the Hsiao-sheng-shui-ssu group.

Niu-hsin-shan is a small hill 69 m above sea level located about 4 kilometers (km) south of Ta-shih-ch'iao station on the Lien-ching line. It consists of magnesite and there is a fissure running north-south in the part about 62 m in relative height and 40 m above level [USGS Ed.: These numbers seem to be reversed.] (the southwestern part of the hill and facing the railway track). This fissure is filled with gravelly clay. The clay consists mainly of breccia of magnesite, and the greater part of the breccia is cemented by calcareous matter. Many fossil bones are found in this breccia formation. The upper part is also filled up with reddish-brown residual clay. In addition to this fissure, there is another fissure at a point about 20 m above sea level on the eastern slope of this hill. The interior is filled by coarse gravelly clay which is not cemented by calcareous matter, and a fossil deer was previously collected from the clay. This bed is considered to lie in the upper horizon as compared with the above-mentioned breccia formation. The writer named the fissure deposits at Niu-hsin-shan the Niu-hsin-shan group.

Niu-hsin-shan group	Lower part:	breccial clay (breccia bed *Trogontherium* bed
	Upper part:	gravelly clay bed reddish-brown residual-clay bed

The foot of the hill is also extensively covered by the Kai-p'ing clay group.

The lower bed closely resembles the breccia bed of the *Sinanthropus* group of Chou-k'ou-tien. The fossils collected from the lower bed [at Niu-hsin-shan] are as follows:

Cervus sp.	Limb bones
Lepus sp.	Teeth
Trogontherium cf. *cuvieri* Fischer	Skull, R M_1 or M_2
Castor sp.	Lower right jaw
Microtus sp.	Teeth
Erinacius cf. *algai* Young ...	Skull, lower jaw
Canis (?) sp.	Skull
Felis sp.	Skull
Phasianus sp.	Skeleton
Ophidia, gen. sp. indet.	
Geoclemys reevesii (Gray)..	Plastron
Anura gen. sp. indet.	Humerus

Among the above listed fossils *Phasianus* is most abundant, therefore, it is no exaggeration to say that the present bed is the *Phasianus* bed. Since *Trogontherium* cf. *cuvieri* occurs in the *Sinanthropus* group at Chou-k'ou-tien, it is an important datum by which the present bed can be correlated with the *Sinanthropus* group. *Castor* sp. is not similar to *Castor* from the *Sinanthropus* group and *Sinocastor* from China; it is rather nearer to *Eucastor*, the living beaver in Canada. These two species of beavers rarely occur in Manchuria. The lower part of Niu-hsin-shan group is correlated with the *Sinanthropus* group at Chou-k'ou-tien, and the sand bed in the lower part of the Hsiao-sheng-shui-ssu group, which is situated at a higher horizon than the Niu-hsin-shan group may be regarded as approximately the same age as the clay bed in the upper part of Hsiao-sheng-shui-ssu group. Thus it has been confirmed that the cave-fissure deposits of the Chou-k'ou-tien stage are distributed in south Manchuria.

TABLE 3. Correlation of the Niu-hsin-shan group and the Hsiao-sheng-shui-ssu group

Kai-p'ing clay group	-----------------
Upper part in the Niu-hsin-shan group	Upper part of the Hsiao-sheng-shui-ssu group
Lower part of the Niu-hsin-shan group	-------------
-------------------	Lower part of the Hsiao-sheng-shui-ssu group

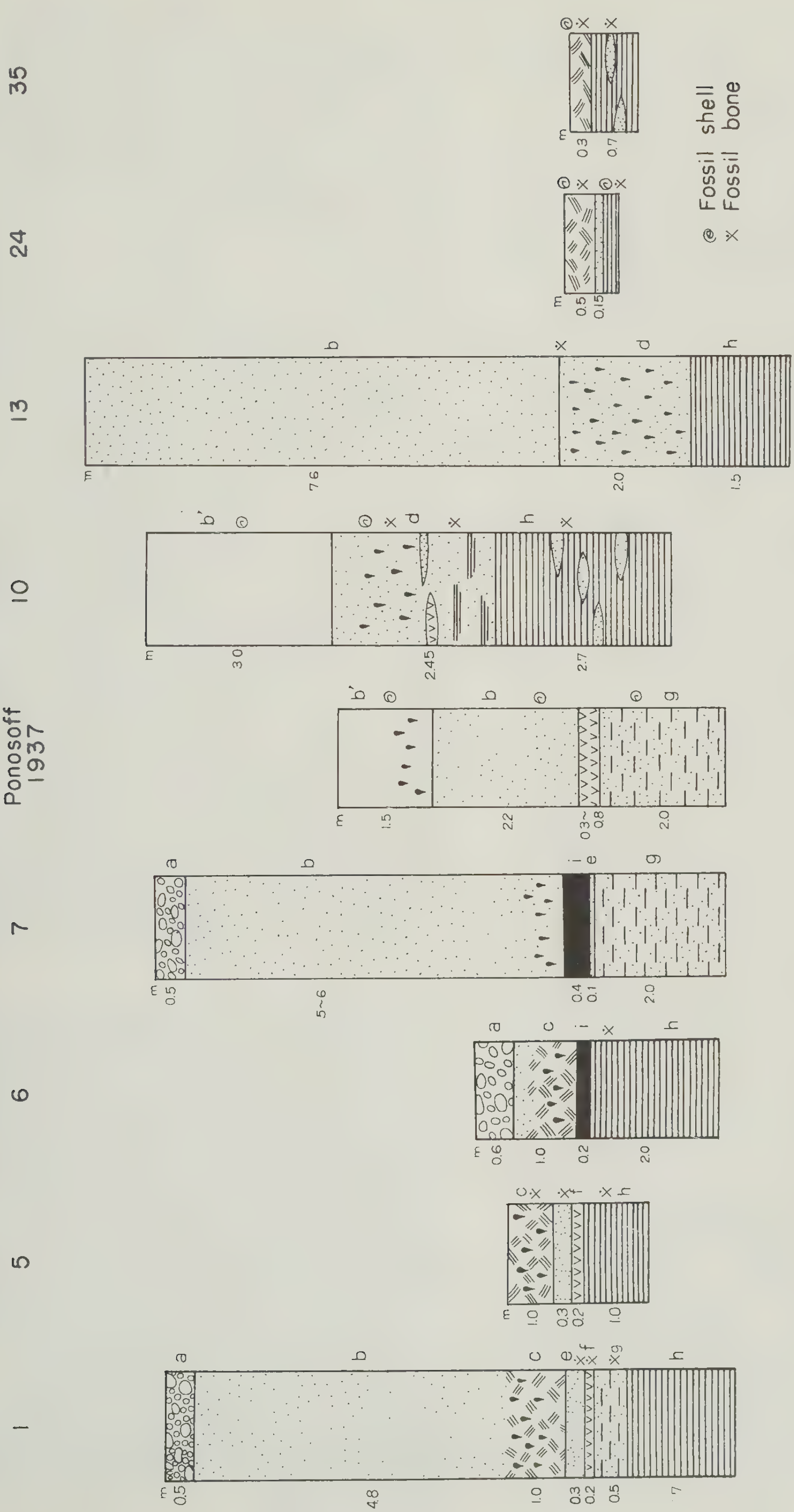


FIGURE 2. Cross section of each excavation trench (1938)
(Numbers refer to locations in text and figure 5)

According to Noda [22], the same fissure deposits are found in a limestone fissure in the vicinity of Ch'ang-t'u, between Ch'ang-sh'un and Shan-yang, from where an antler of Cervus hortulorum gravi (Zdansky) was collected.

LIAO HO PLAIN GROUP

In south Manchuria, loess or loesslike clay is extensively distributed. According to Fusao Uedo and Masao Sasakura [40], the Diluvium series in Chin-chou, Jehol, and Hsing-an province fills the great valleys or covers the hills, and it consists of loess, sandy loess, and eolian sands. The loess is mainly developed in the southern part and it grades toward the sandy loess in the middle part. A basal gravel bed is occasionally found and a gravel bed is sometimes intercalated in the middle part. Its distribution centers are Ch'eng-te, Chang-shan-yu [between Ch'eng-te and Ku-pei-k'ou], Ku-pei-k'ou, Hwai-jou [south of Mi-yün], Hsing-lun Hsien, P'ing-chüan, K'uan-ch'eng, Sa-ho-ch'iao, Ch'ih-feng, Ling-yüan, Ch'ao-yang, Chien-chang [another name for Ling-yüan], and Sui-chung, and the sandy loess is distributed extensively and covers the hills in the area north of the line which connects Ch'ih-feng, Pien-ch'iang-shan, and Kuo-chia-tun as far as Wu-tan-ch'eng. The sandy loess which covers the hills is relatively thin, but its thickness attains 20 to 30 m in the valley vottoms and it also intercalates the gravel beds.

In the Liao-hsi district which is the coastal area of Liao-tung bay east of Shan-hai-kwan [Lin-yü] especially in the wide valleys of the hills of old mature stage in the Sui-chung district, a loess bed is distributed at a height of scores of meters above sea level. This loess bed intercalates gravel beds and differs somewhat from the loess in north China. A reddish-clay bed is sporadically developed in its lower part. In the valleys which dissected this loess bed, black earth has been deposited, 1 to 2 m thick, and a part of it has changed into a peatlike substance. It is noteworthy that the loess bed in Liao-hsi resembles the Kai-p'ing clay in Liao-tung on the whole rather than the loess in Jehol. The same relation is found at Ta-ku-shan and along the Chuang Ho -- the Liao-tung peninsula on the coast of the Yellow sea [Korea bay]. In the area south of the Chuang Ho, a terra-rossa-like red clay, which resembles the Chin-chou clay found in the vicinities of Chin-chou, is developed extensively and covers the plane of the low-level hills on the coast. However, in the Ta-ku-shan district, it is completely absent and a yellow-clay bed (the Ta-yang-ho yellow-clay bed) is extensively distributed. Its characteristics are not very different from that in Liao-hsi. The deposition plane is scores of meters above sea level and it coincides with the P'i-tzu-wo plane, and some of the yellow clay was drifted (washed?) secondarily to the lower places. On the greater part of the coast a peat bed is found which is mined by the inhabitants (the Ta-ku-shan peat bed). In Chang-chia-pao, 20 km northeast of Ta-ku-shan, there is a peat bed at a depth of about 1 m; and it is 80 cm thick. In Chien-shan-tzu, 8 km northeast of Chang-chia-pao, it is 1 to 2 m thick [1]). This peat bed may be correlated with those in Pyongan-pukto and the Chongju district of Pyongan-namdo, Korea. Such peat beds are extensively distributed in the bay head of an old stage along the drowned coast of north coast of of the Yellow sea.

On the Liao-tung peninsula, a remarkable red earth is developed in the Chin-chou district and its characteristics resemble the Pei-piao red earth in Jehol. Though the red earth yields no fossils and positive data are not yet found, the writer wants to correlate tentatively this red earth and the Pei-piao red earth with the Pao-te red earth (Chin-chou clay group). Red earth is also sporadically distributed on the hills of low altitude in the so-called Liao-tung plain situated between Chin-chou and Ta-shih-ch'iao [10]. Heretofore these red earths have been regarded as terra rossa which is due to the weathering of limestone. However, the red earth is found in places other than limestone districts, and in the limestone districts of northeastern Manchuria, such red earth is not found even in the form of rendzina. Therefore, the writer strongly doubts whether such reddish-clay group may be distributed in northeastern Manchuria. The P'u-lan-tien clay bed forms the P'i-tzu-so plane in prolongation may be the mammoth-bearing clay bed at Lung-wang-tan in Ta-lien. The P'u-lan-tien peat bed, bearing seeds of Indian lotus (the experiment of germination was made), was deposited in the bottoms of valleys which dissected the hills consisting of the P'u-lan-tien clay bed. This P'u-lan-tien peat bed is merely a prolongation of the Ta-ku-shan peat bed.

In the Kai-ping and Ta-shih-ch'iao districts the Kai-p'ing clay group, which is the prolongation of the P'u-lan-tien clay bed, is extensively distributed on the low-level planes about 7 m± above sea level. Small erosion valleys have been developed in a part of the Kai-p'ing clay group by present erosion. There are many gullies on the clay which cover the slopes of hills. These gullies may continue to the small erosion ravines in the valleys. The formation from which Palaeoloxodon namadicus was collected, in the vicinity of Pei-piao, may be a prolongation of the present clay bed. According to Saito [26], in Tang-kang-tzu hot spring south of An-shan, the earthy formations in descending order from the surface are: black earth (6. 2 to 15 m), loess (4. 5 to 14. 5 m), and sand bed (2. 9 to 6. 9 m). This is also a northward prolongation of the Kai-p'ing clay group. According to Shōichi Nishida [20], the following section was obtained in the vicinity of Hsing-cheng hot spring, Chin-chou province:

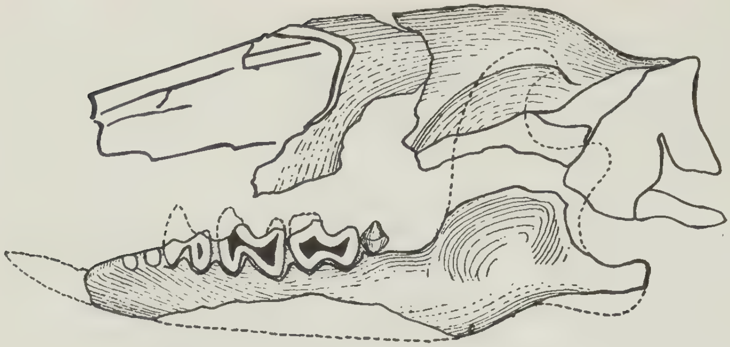
1. Surface soil .... 60 cm
2. Dark-brown fine sand .... 60 cm
3. Brown coarse sand .... 80 cm
4. Gray-brown coarse sand .... 150 cm
5. Gravel (pebbles of 3 to 5 cm in diam.) 100 cm
6. Gravel (pebbles of 5 to 10 cm in diam.) 300 cm
7. Light-green clay .... 90 cm
8. Granite ....

This area is the alluvial coast of Po Hai and gravel beds which were deposited by the Liao Ho are extensive. The alluvial area which is surrounded by Shen-yang, Hsin-min, Hei-shan, Hai-ch'eng, and Yin-k'ou is remarkable. Liao-tung bay, which had extended as far as Shen-yang and Hsin-min districts in the early Alluvium, may have been buried by the prolongation of deltas formed by the Ta-liao Ho [Liao Ho], T'ai-tzu Ho, Hun Ho, Sha Hŏ, Hsiao-ling Ho, and other rivers.

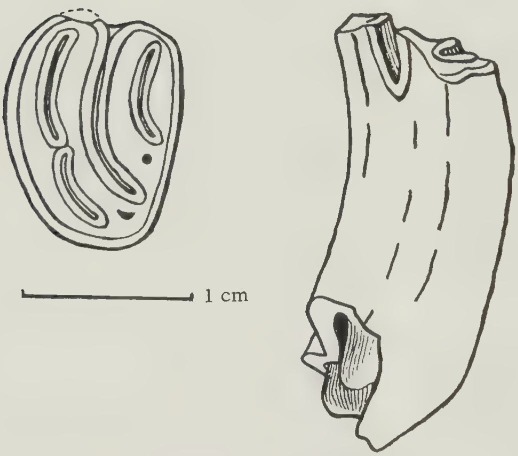
According to Kuma Haraguchi [11], who surveyed the dam of Liao Ho reservoir northwest of K'ai-yüan, loess 20 m thick overlies the Chuan-tou formation on the hills between Ho-t'o-lo and Chai-chia-wo-peng, and mammoth and deer were collected in the vicinity of Pao-li-chen. On the left bank of the Liao Ho, loess was deposited, while on the right bank eolian sands (1 and 2 m) are found on the surface, and sand mixed with clay is developed under the surface sands. Haraguchi considers that this sand bed is younger than the loess.

A thick group of yellow clay is developed in an area from Shen-yang to Ch'ang-ch'un and forms hills of strong relief (the Liao Ho plain group). The group in part consists of homogeneous compact loesslike clay, however, a part of the group is mixed with gravel. Mammoth remains were found in the gravel bed which forms a terrace in the Ying-ch'eng-tzu coal mine. Mammoth remains were also collected from the same bed at Liu-ho east of Shen-yang. In short, the Liao Ho plain group is the southern prolongation of the Ku-hsiang-t'un formation and it corresponds to the marginal part of the Manchurian facies or the transition to the north Chinese facies. The Chuan-tou (Sento) formation (Cretaceous) near Ch'ang-t'u extends as far as north of Ch'ang-ch'un and is overlain by the clay of the Liao Ho plain group. As is seen in Ping-ting-shan at Ta-t'un, south of Ch'ang-ch'un, a basalt flow truncates the Chiang-t'u bed and seems to be overlain by the clay group. This basalt flow may have some relation with the volcanic activities of Chi-hsing volcano and P'ai-t'ou Shan as well as the formation of basalt plateaus in Mu-tan-chiang province.

In 1930, Licent and Teilhard de Chardin [17] reported the following fossils, which are equivalent to the Ku-hsiang-t'un facies, from Ou Tao Chuang, southwest of Ch'ang-ch'un: <u>Elephas</u> sp., <u>Equus hemionus</u>, <u>Equus</u> cf. <u>przewalskyi</u>, <u>Cervus orosianus</u>, <u>Gazella</u> sp.,, and <u>Bison</u> sp. They reported the presence of a red coarse-grained gravel bed which forms the Ch'ang-ch'un hills plane and underlies the Liao Ho plain group, and assigned it to the San-men series. However, the writer considers that it probably belong to the Chou-kou-tien stage. Moreover, they also reported the presence of white-gravel bed (8 to 12 m) in the basal part of the yellow-clay bed in the interior of the basin. This may be a sandy facies which is seen in the lower part of the Ku-hsiang-t'un bed. The afore-mentioned section reported by Yamamoto is located in the vicinity of this place, and, so to speak, it is the type section of the area along with the so-called Hei-liao divide [19]. The stage of formation of this divide, namely, the stage when the water courses of the Liao Ho and Sung-hua Chiang were fixed may have been after the deposition of the Liao Ho plain group and before the deposition of the black earth. That is, it was a re-occurring upheaval which accompanied the Liao Ho erosion. This upheaval movement coincides with the development of terrace-forming movement of large scale in the Japanese islands at the end of J_2 stage (Musasino terrace - Du plane) [30]. If the Hei-liao divide can be regarded as the Korean direction, it is considered that this movement may be related with the movement which caused the declination of high-level plane in Korea and subsequently caused the difference between the topography of the east coast and that of the west coast in Korea [15]. The subsidence topography of the Liao-tung peninsula is in accord with the subsidence topography of the west coast of Korea. The north-western prolongation of the eastern shore line in Korea coincides with the Hei-liao divide. It is worth considering whether the movement of the Hei-liao divide was already begun at the Ching-shui stage or not. Since the boundary between the Manchurian facies and the north Chinese facies approximately coincides with the Hei-liao divide, the first movements of the Hei-liao divide may already have begun in the Ching-shui stage. According to Kunitarō Niinomy, the New Chiang and Laio Ho were originally one continuous river; then they were cut in two by the Hei-liao divide and the Nen Chiang became a tributary of the Sung-hua Chiang. The cutting of this antecedent valley probably occurred in the Lao-ha stage. If the Nen Chiang and Liao Ho flowed southward as a single river, the Manchurian facies and north Chinese facies may come in contact along the same river, and the Ssu-p'ing-shih - Cheng-chia-t'un [Liao-yüan] districts may not have been dissected. Therefore, Niinomy's opinion conflicts with the fact. It is rather reasonable to consider that one continuous river flowed northward emptied into the Sung-hua Chiang and the Lao-ha Ho flowed via the upper stream of the former Liao Ho and poured into the Sung-hua Chiang. It is noticeable the that district of Cheng-chia-t'un, Kan-an, Chien-kuo-chi, and Ta-lai is a vast alluvial zone and no hill consisting of loess is found.



Erinaceous cf. algai Young



Trogontherium cf. cuvieri Fischer

Castor sp.

FIGURE 3. Vertebrate fossils from Niu-hsin-shen group

The localities where fossils have been found in the Liao Ho plain group are as follows:

1. Water reservoir at Lung-wang-tan, Ta-lien [38]: In 1921, an elephant tusk and a tooth were found in the clay and gravel bed under the river bed during the engineering work. They are in the possession of Tatsuo Okuwa.

2. Water reservoir at Lo-chia-tun in the vicinity of Ta-lien: elephant tusks.

3. Excavation connecting the first excavation with the third excavation at Ling-shui-ho, Hsiao-p'ing-tao-hui in Ta-lien district: tusk, vertebrae, and scapula of mammoth were found in 1916 and they are owned by the Museum of Port Arthur.

4. Southwest of Ch'ao-yang in Jehol province: Rhinoceros antiquitatis was found by Teilhard de Chardin in the loess.

5. Ch'ao-yang-kou, north of Ch'ih-feng, Jehol province: Rhinoceros antiquitatis (molar), Ovis ammon (occipital bone), mammoth and bone implements were found by Saburō Shimizu, Isao Matsuzawa, and others in the loess deposits.

6. Shore of the Lake Borden [USGS Ed.: location unknown]: fragment of deer antler which was artifically worked and skull of Meles. They were found by Hisakichi Hishida in 1920.

7. Luan-p'ling district in Jehol province: deer of giant antlers.

8. Sinmin[Hsin-min] Hsien, Feng-tien province (Shen-yan province): skull with two two horns of Bos primigenius. It is said that this specimen was formerly possessed by the Shen-yang Museum. It was found in the sand bed.

9. Liu-ho [USGS Ed.: a village now called Chih-an-p'u]: molar of mammoth found in a river bed.

10. Hsiao-ky-lun [K'u-lun-chieh] in Jehol province: Molar of mammoth in collection of the Geological Survey Museum of South Manchurian Railway Co. in Ta-lien.

11. Ssu-p'ling-shih in Chi-lin province: Fragment of incisor of mammoth and fragment of horn of Bos primigenius which were possessed by the former Museum of Port Arthur.

12. Kung-chu-ling in Chi-lin province: Tusk and femur of mammoth as well as skull, and molar of Rhinoceros antiquitatis and other bones which were found in the loesslike clay and were possessed by the former Manchurian Medical College in Mukden [Shen-yang].

13. Hua-shih-ling [Ying-ch'eng-tau] coal mine [near Chiu-ta'i], east of Ch'ang-ch'un.

14. Ou Tao Chuan, southwest of Ch'ang-ch'un.

15. In the vicinity of Pei-piao: Palaeoloxodon Namadicus [33].

KU-HSIANG-TUNG (KOKYŌTON) FORMATION

Fossil mammalia discoveries in north Manchuria (after Tokunaga and Naora [38]:

1905 -- A. D. Hitrob collected a skull of buffalo on the River Bodounet [USGS Ed.: location unknown, probably in Chi-lin area], the upper stream of the Sung-hua Chiang and sent it to the Kiakhata Museum [U. S. S. R.]. Later, it was studied by M. Pavlov.

1909 -- Raikob found a bone which is probably mammoth on the bank of Mu-tan Chiang south of Ningkuta [Ning-an].

1911 -- Raikob found a fossil bone on the River Ushagou [sic] in the vicinity of Mt. Hunchung Shan.

1918 -- The skulls of mammoth, bison, rhinoceros,and others were found in the upper deposit at the Djalainor coal mine.

1923 -- Rhinoceros was found on the Nen Chiang.

1924 -- Mammoth was found at Shduch'ya village on the River Derubur [Reka Derbul or Chich-erh-pu-erh-lo Ho], a tributary of Argun river, in the Barwa [sic] district.

1925 -- Rhinoceros and mammoth were found on the lower stream of the Nen Chiang, 5 km from Fularki [Fu-la-erh-chi].

1926 -- A tusk of mammoth was unearthed in a cliff 100 m east of Nichiro-Kyōkai College [Harbin].

1926 -- Bison was discovered on the River Umingora [I-min Ho], 25 km south of Hai-la-erh,

1927 -- Mammoth was found at a place 10 km from Bodounet where buffalo was unearthed in 1905.

1927 -- Bison and mammoth were found at "Gordor" (probably Gorbunor [O-erh-pu-no-erh/4944/12036] village on the left bank of the River Mergera [Mo-erh Ho] 80 km north of Yakeshih [Ya-k'o-shih] station.

1927 -- Parietal of rhinoceros was unearthed at a place 12 km southwest of Man-chou-li station [Lu-pin]. Mammoth was found in the ground of a school in Man-chou-li.

1927 -- A milk molar of mammoth was discovered on the Sung-hua Chiang at T'ao-lai-chao.

1927 -- Mammoth was found during well-sinking in the vicinity of No. 551 Branch Office in Harbin.

1927 -- Rhinoceros and mammoth were found in a cliff of a small river 2 km distant from the No-erh Railway.

1927 -- Fossils of mammoth were found on the I-min Ho and on the Uhelohe river, a tributary of the former.

1928 -- A fossil bone was found during the well-sinking at Cartu Station [USGS Ed.: Location uncertain; may be Ho-erh-hung-te near Hai-la-erh].

1928 - Vertebrae of rhinoceros were found at a place 20 km northwest of Hai-la-erh.

1928-29 -- Belebeki collected many fossil bones from the bottom of Sung-hua Chiang between Harbin and Chenghe [USGS Ed. : Location of Chenghe uncertain; may be T'ung-ho, lat 45° 59', long 128° 43'].

1930 -- Skull of bison was unearthed on the Hei-lung Chiang [Amur river] in the vicinity of Hei-ho [Ai-hun].

1931 -- The Harbin Museum and the Peiping Geological Survey carried out unearthing at Ku-hsiang-t'un.

1932 -- Mandible of rhinoceros and other fossils were found from the river sand in the river bed of Sung-hua Chiang during the construction of piers [USGS Ed.: This refers to the construction at a bridge where the railroad from Ch'ang-ch'an to Ha-erh-pin crosses the Sung-hua Chiang.].

1933 -- The first digging at Ku-hsiang-t'un by Shigeyasu Tokunaga, Nobuo Naora, and others, who took part in the First Scientific Expedition

to Manchoukuo and Mongolia.

1934 -- The second digging at Ku-hsiang-t'un by Tokunaga and Naora (also Shimeji Ōta and Seikō Makido).

1937 -- The first digging at Ku-hsiang-t'un by the Central Museum of Manchoukuo (Endō, Ishijima, and Naoei Okuda).

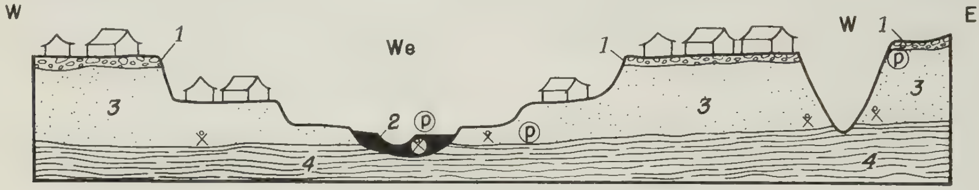
1938 -- The second digging at Ku-hsiang-t'un by the same museum (Shikama and Mitsuo Noda, also Endō, Ishijima, and Okuda).

Forming of terrace:	Dissection of the Wen-Chuan Ho (Sung-hua Chiang stage)

Though the upper Ku-hsiang-t'un formation consists of apparently homogeneous loesslike clay, it is remarkably arenaceous as compared with the Ma-lan loess.

Lower bed

The variation in the lower bed is remarkable;



We = Wen-chuan Ho ; W = Wa-pen-yao Ho ;

1. Brick earth and surface soil;
2. Black earth (Wen-chuan-ho bed);
3. Upper Ku-hsiang-t'un bed ;
4. Lower Ku-hsiang-t'un bed ;

Ⓟ Paleolithic-implement site ;

Fossil bone and teeth site .

FIGURE 4. Profile in the vicinity of Ku-hsiang-t'un

Ku-hsiang-t'un, a treasury of Diluvium fossils, ia a village located along the Wen-chuan Ho, a tributary of Sung-hua Chiang, 5 km southwest of the center of Harbin [Ha-erh-pin]. The Diluvium series crops out along the Wen-chuan Ho and its tributary Wa-pen-yao Ho. The Diluvium series, which forms the terrace group in the vicinity of Harbin, is estimated to be about ± 25 m. In the vicinity of Ku-hsiang-t'un, its average thickness is about ± 10 m. It consists of a succession of clay, mud, sand, sandy clay, and other sediments, and it is one kind of flood-plain lacustrine deposit. It is different from the Ma-lan loess, in that remarkable gravel beds are not found in it. The succession of the Ku-hsiang-t'un formation is as follows [27]:

Ku-hsiang-t'un formation	lower part:	Bluish-gray to dark-gray clay bed and sandy-clay bed.......... 2.8 m
	upper part:	Yellowish-gray argillaceous sand to sandy-clay bed bed.........10 m
Forming of terrace:		Dissection of the Wa-pen-yao Ho (Wa-pen-yao stage)
Wen-chuan-ho bed:		Black-mud bed (± 1 m average thickness)

a clay bed is predominant in the lower part and an arenaceous-clay bed in the upper part. In ascending order, the section is composed of:

1. Dark-gray clay (2.7 m in maximum thickness): It consists of fine-grained and highly coagulated clay, and it passes into dark compact massive clay and, in places, into yellow clay in the upper. Lenticular zone of yellow compact medium-grained sand is intercalated within it.

2. Bluish-gray arenaceous clay bed (1 to 2 m): arenaceous clay or arenaceous mud in which a fine-blue color is predominant. Compact, soft and massive. Drift woods and other inclusions are scanty.

Upper bed

In general, sands predominate and cross-bedding is common in its lower part. The kind of basal conglomerate is found in the lowest part and it seems that a slight unconformity exists, though not yet confirmed.

1. Bluish-gray clay bed consisting of clay pebbles (0.8 m maximum thickness, 0.2 m average thickness). It is well exposed along the Wa-pen-yao Ho and sometimes it is intercalated in lenticular forms. The pebbles consist of well-rounded clay pebbles or breccia, 1 mm in diameter, which are derived from bluish-gray

arenaceous-clay bed. It may be a kind of basal conglomerate. It contains sporadically dark-colored compact humuslike or peatlike clay, and it also contains many drift woods.

2. Yellowish-gray to yellowish-brown sands, argillaceous sands, and arenaceous-clay bed (10 m maximum thickness. Its upper limit is still unknown). Cross-bedding is predominant in the lower part, and bog irons as large as a tip are distributed uniformly. This bed corresponds with Tokunaga and Naora's loesslike clay bed as well as Ponosoff's argillaceous loess-like clay bed. The upper part of this bed has been changed partially into black porous soil and in the part near the surface Ponosoff recognized some podosolization. In some parts the following minute land mollusks are aggregated densely: 1) Gyraulus chmacheri Clessin, 2) Lymnaea (Galva) pervia v. Martens, 3) L. (Radix) auricularia coreana v. Martens.

Mammals and other fossils are abundant in the lower part of the yellowish-gray sands, where cross-bedding is predominant, and in the upper part of the other units. Zoning based on fossils is impossible, and the upper and lower part are of similar character; they are probably of the same age. Most of fossil mammals are water-worn fragments and a complete skeleton is seldom found. In this respect the bed coincides with the flood-plain deposits which are heavily cross-bedded. A Mousterian-type scratcher was found in the upper part of the dark-gray clay. Localities 19 and 20 (fig. 5), in which the most abundant fossils and human relics were found in the second digging by Tokunaga and Naora, are in the upper part of the dark-gray clay and the localities do not belong to the Wen-chuan-ho bed. The Wen-chuan-ho bed contains many fossil bones which were carried from the Ku-hsiang-t'un formation by running water. The fossils of Juglans manchurica Max. is an example of the peculiar fossils of the Wen-chuan-ho bed. Fragments of fossil bones were carried from the Ku-hsiang-t'un formation or the Wen-chuan-ho bed by the running water are found on the present river bed mixed with bones of domestic animals of the present time. The width of the river flood plain of the Wen-chuan-ho, namely, that of deposition plain of the Wen-chuan-ho bed is estimated to be about 240 to 260 m. It is flat and is utilized as a clay pit by brick-manufacturing factories at Ku-hsiang-t'un; in this way, the presence of fossil bones became known. Many digging trenches of Tokunaga and Naora are located in the vicinity of the confluence of the Wen-chuan Ho and Wa-pen-yao Ho and at a point downstream from the iron railroad bridge which crosses the Wen-chuan Ho. They dug in the deposition plane of the Wen-chuan Ho in each excavation. The Wen-chuan-ho bed is thickest in the vicinity of the iron bridge. In contrast, the Ku-hsiang-t'un formation crops out in the area downstream from the confluence of the Wen-chuan Ho and Wa-pen-yao Ho.

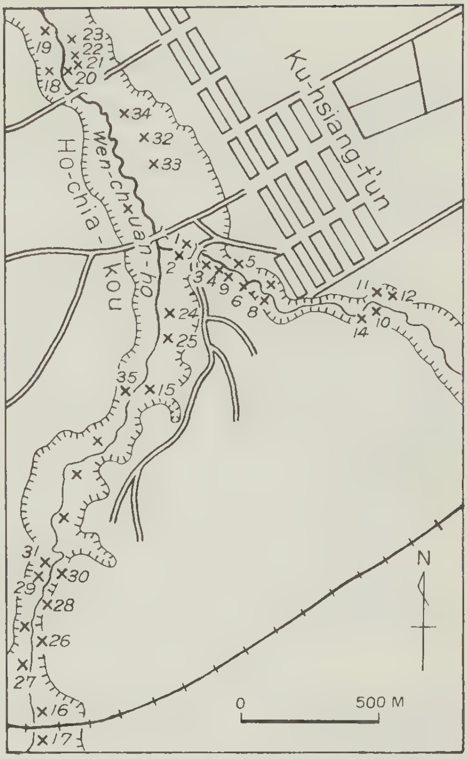


FIGURE 5. Distribution map of excavation trenches at Ku-hsiang-t'un in 1938 (numbers refer to text and figure 2)

In the second digging by the Central Museum of Manchoukuo, stress was laid on the research of the Ku-hsiang-t'un formation and every possible effort was made in the diggings of the Wa-pen-yao Ho. Digging locality 1, 2, and 8 (fig. 5) were in the Wen-chuan-ho bed alone. Many good specimens were collected by dredging the river floor. This method was faster than digging in the solid beds.

The fossils from the Ku-hsiang-t'un are abundant, and if the Tokunaga and Naora's collection is included, they are as follows:

MOLLUSCA

1. Unio eulasiae amurensis Mouson
2. Cristaria plicata (Lea.) var. Suzuki
3. Spharerium lacustre compresum Mous.
4. Valvata piscinalis manchurica Suzuki
5. Stenothyra tokunagai Suzuki
6. Bulimus (B.) ussuriensis harupinensis Suzuki
7. B. (Parafossarulus)striatulus Benson
8. B. (Gobbia) kiusiuensis naorai Suzuki
9. Semisulcospira cancelata amurensis (Gers.)

MOLLUSCA (Concluded)

10. Carychium pessimum gerstfeldti Schi.
11. Aplexa hypnorum (L.) subsp.
12. Lymnaea (Galba) pervia v. Martens
13. L. (Stagnicola) tokunagai Suzuki
14. L. (Radix) auricularia coreana v. Martens
15. L. (R.) plicatula Benson
16. Anisus gredderi (Biel.)
17. Hippeutis manchuricus Suzuki
18. Succinea pfeifferi pingi Suzuki
19. S. alpestris Alder
20. Cochlicopa lubrica (Müll)
21. Vertigo alpestris Alder
22. V. alpestris harbinensis Suzuki
23. Gastrocopta coreana Pils.
24. Vallonia chinensis Suzuki
25. Gonyodiscus ruderata pauper (Gould)
26. Euconulus sp.
27. Bradybaena staoi Suzuki
28. B. virgo (Pils.)

INSECTA

Coleoptera indet. Naora

PISCES

1. Ctenopharyngdon cf. idella (Vald.)
2. C. sp. Naora
3. Carassius sp. Naora
4. Pelteobagrus sp. Naora
5. Leiocassis sp. Naora

AVES

1. Struthio sp. Tokunaga and Naora
2. Phasianus sp. Tokunaga and Naora

REPTILIA

Amyda maackii (Brandt.)

MAMMALIA

Carnivora

1. Canis lupus L.
2. C. sp. Tokunaga and Naora
3. Nyctereutes sp. Tokunaga and Naora
4. Vulpes cf. vulpes (L.)
5. Urus cf. spelaeus Blum.
6. Meles sp. Tokunaga and Naora
7. Mustela cf. sibirica Pallas
8. Hyaena ultima Matsumoto
9. Panthera tigris (L.)
10. Felis catus L.

Rodentia

1. Clethrionomys rufocanus (Sund.)
2. Microtus cf. rattoceps (Young)
3. Microtus cf. pelliceus Thomas
4. M. (lasiopadomys) brandti (Radde)
5. M. obscurus (Evers)
6. M. cf. monoglicus Radde

MAMMALIA (Concluded)

Rodentia (Concluded)

7. M. (Stenocranius) gregalis (Pall.)
8. Cricetulus griseus Milne-Edwards
9. Siphneus sp. Tokunaga and Naora
10. Ochotona cf. manchurica Thomas
11. Citellus mongolicus (Milne-Edwards)
12. Marmota manchurica Tokunaga and Naora
13. M. robusta (Milne-Edwards)
14. M. bobac sibirica (Radde)
15. Tamias sp. Tokunaga and Naora
16. Castor orientalis Tokunaga and Naora

PERISSODACTYLA

1. Atelodus antiquitatis (Blum.)
2. Rhinoceros sinensis Owen
3. R. cf. mercki Jäger
4. Equus przewalskii Pol.
5. Equus homionus Pallas

ARTIODACTYLA

1. Sus continentalis Nehr.
2. S. cf. lydekkeri ZD.
3. Capreolus manchuricus (Noak)
4. Cervus (Cervus) canadensis xanthopygus Milne-Edwards
5. C. (C.) elaphus L.
6. C. (Sinomegaceroides) ordosianus Young
7. C. (Sika) hortulorum grayi (Zdansky)
8. C. (Rusa) elegans Teilhard de Chardin and Piveteau)
9. C. (Sika) nippon manchuricus (Swinhoe)
10. Alces sp. Teilhard de Chardin
11. Elaphurus cf. menziesianus (Sow.)
12. Giraffidae, gen. and sp. indet. Tokunaga and Naora
13. Gazella cf. gutturosa Pallas
14. Spiroceros kiakhtensis Pavlova
15. Bos primigenius Boj.
16. Bison priscus Boj.
17. Bubalus tielhardi Young
18. Probubalus sp. Loukashkin
19. Bibos kuhsiangtungensis Tokunaga and Noara
20. Camelus sp. Loukashkin

PROBOSCIDEA

1. Mammuthus primigenius (Blum.)
2. Parelephas armeniacus

PRIMATES

1. Gen. and sp. indet.

Among them Mollusca were identified mainly by Kōichi Suzuki [31]. However, it is not clear how many species were from the

Ku-hsiang-t'un formation and how many from the Wen-chuan-ho bed; moreover, the fossiliferous horizons in the Ku-hsiang-t'un formation itself are indistinct. Therefore, the writer listed them merely as one group. The following plant fossils were reported by Tokunaga and Naora, and most of them belong to the Wen-Chuan-ho bed: 1) Trapa natans L. subsp., 2) Salix sp., 3) Juglans manchurica naorai Endo, 4) J. manchurica tokunagai Endo, 5) Betula alba L., and 6) Hordeum sp.

According to Endo's [5] identification, the collection from the second digging of the Central Museum of Manchoukuo expedition (in 1939) follows. From this list, one may see the frequency of fossils from the Ku-hsiang-t'un formation and of those which were washed out by water. The numbers that follow the names of bone indicate the number of specimens; the fossils without numbers mean that only one specimen was found. [USGS Ed.: The trench numbers probably refer to fig. 5].

TRENCH 1

Equus hemionus Pallas	Lower tooth
Bos primigenius Boj	Lower jaw, phalange
Alces sp.	Antler
Atelodus antiquitatis (Blum.)	Skull fragment, scapula fragment
Bison priscus Boj.	Humerus, scapula
Cervus (Sika) nippon manchuricus (Swinh.)	Innominate bone

TRENCH 2

Atelodus antiquitatis (Blum.)	Upper tooth, axis, manus
Equus hemionus Boj.	Lower teeth (3), phalange
Cervus (Sika) nippon manchuricus (Swinh.)	Lower teeth (2), axis, pes, manus, femur
Capreolus sp.	Humerus
Bos primigenius Boj	Pes, manus, tibia(?), innominate bone, bone implements (9)
Canis lupus L.	Manus

TRENCH 3

Bovidae	Upper tooth
Bos primigenius Boj	Manus
Atelodus antiquitatis (Blum.)	Skull fragment, pes
Felidae	Manus

TRENCH 4

Atelodus antiquitatis (Blum.)	Upper tooth, vertebrate, femur

TRENCH 5

Atelodus antiquitatis (Blum.)	Lower teeth (4), skull fragments (2), atlas, cervical vertebrae (3), lumbar vertebrae (2), femur (3), manus, costa (3)
Equus hemionus Pallas	Phalange
Cervus (Sika) nippon manchuricus (Swinh.)	Lumbar vertebrae (3), femur
Bos primigenius Boj	Lower teeth (6), manus, pes (2), calcansum (2), scapula, ulna
Gazella cf. gutturosa Pallas	Horn core
Nyctereutes sp.	Femur
Felidae	Manus
Mammuthus primigenius (Blum.)	Vertebrae, costa

TRENCH 6

Equus hemionus Pallas	Pes, manus (2)
Capreolus manchuricus (Noak)	Antler, scapula, lower tooth
Cervus (Sika) nippon manchuricus (Swinh.)	Pes, lumbar vertebrae, atlas sacrum, femur, ulna
Bos primigenius Boj	Humerus (2), ulna (4), tibia (2), femur, scapula (4), astragalus (4), calcaneum (2), pes (2), phalange (2)
Bison priscus Boj	Horn core, lumbar vertebrae (2), manus (2)
Felidae	Manus
Mammuthus primigenius (Blum.)	Costa (12)
Bone implements	12

TRENCH 10

Atelodus antiquitatis (Blum.)	Upper tooth
Equus hemionus Pallas	Phalange, manus (2)
Cervus sp.	Radius
Bos primigenius Boj	Lower tooth, calcaneum, manus, radius, tibia, scapula, astragalus
Bone implement	1

TRENCH 13

Equus hemionus Pallas	Phalange
Capreolus sp.	Scapula
Bison priscus Boj	Ulna, calcaneum
Mammuthus primigenius (Blum.)	Crapus, scapula

TRENCH 18

Equus hemionus Pallas	Manus
Cervus (Sika) nippon manchuricus (Swinh.)	Femur
Bison priscus Boj	Calcaneum, tibia
Martes sp.	Lower jaw

TRENCH 32

Pisces	Operculum
Struthio sp.	Egg shell
Atelodus antiquitatis (Blum.)	Lower tooth, axis, sacrum, manus
Equus hemionus Pallas	Lower tooth, manus, phalange
Capreolus manchuricus (Noak)	Humerus, phalange, calcaneum, costa
Bos primigenius Boj	Lower tooth, lower jaws (2)
Stone implement	1

TRENCH 33

Equus hemionus Pallas	Lower tooth
Cervus sp.	Femur, sternum
Meles sp.	Femur

TRENCH 35

Atelodus antiquitatis	Upper tooth, lumbar vertebra, axis, manus, radius, scapula (2), humerus, costa
Equus hemionus Pallas	Upper tooth, lower teeth (2), manus
Cervus (Sika) nippon manchuricus (Swinh.)	Atlas, ulna, manus, innominate bone
Bos primigenius Boj	Upper teeth (2), lower tooth, calcaneum, astragalus, ulna
Mammuthus primigenius (Blum.)	Tusk, molar
Bone implement	1

DREDGED FROM THE WEN-CHUAN-HO RIVER

Atelodus antiquitatis (Blum.)	Upper teeth (13), lower teeth (5), manus (2), skull fragments (2), radius, ulna, cervical vertebrae (3), sacrum (2)
Equus hemionus Pallas	Lower teeth (9), upper teeth (5), lower jaw, manus (3), phalanges (3), metatarsus (5), phalanges (2)
Capreolus manchuricus (Noak)	Antler, manus (3), calcaneum (2), phalange, manus, scapula, radius, humerus
Cervus canadensis xanthopygus M. E.	Antler
Cervus (Sika) nippon manchuricus (Swinh.)	Teeth (4), humerus (6), manus (7), phalanges (2), lumbar vertebrae, costa, astragalus, carpus
Bos primigenius Boj	Lower teeth (7), upper teeth (7), phalange, calcaneum (3), tibia, metatarsus (5), costa (5), lumbar vertebrae (2), innominate bone, radius, astragalus
Bos sp.	Lower jaw
Bison priscus Boj	Ulna
Bison sp.	Tibia
Canis lupus L.	Skull, teeth (10), manus
Canidae	Manus, humerus, radius
Microtus sp.	Lower jaw (much in number)
Siphneus sp.	Lower jaw (much in number)
Mammuthus primigenius	Manus
Phasianus sp.	Scapula

Of the above fossils most abundant are rhinoceros, wild Bovidae (bison Bos), wild horse, and deer; and rats are next. Rodentia was especially abundant in trench 19. In the

above list, Equus przewalskii was included in E. hemionus. The presence of Struthio, Castor, Gazella, Bubalus, and Camelus is interesting. According to Tokunaga and Naora, mammals of 61 species in total show the following percentages. Numbers in parenthesis indicate specific number of specimens.

Mammals	Percentage of living species	Percentage of extinct species
Carnivora	9 (6)	8 (5)
Rodentia	19 (12)	6 (4)
Artiodactyla	14 (9)	29 (18)
Perissodactyla	3 (2)	6 (4)
Proboscidea	-	1 (1)

Of these 61 species, the number of extinct and of living species is respectively 32 (52 percent) and 29 (47 percent). Forest, steppe, and marsh-river animals are respectively 26 (42 percent), 30 (49 percent), and 5 (8 percent). Species now living in Manchuria are 20 (32 percent), while those living outside of Manchuria are 8 (13 percent). Of the extinct species, 5 (8 percent) are known in the Far East, while 7 (11 percent) are reported from outside Manchuria; the remaining 21 (34 percent) are found in Manchuria alone. It is said that 8 (13 percent) were found in the lower Diluvium, while 53 (85 percent) were collected from the middle and upper Diluvium (the Ma-lan stage). The percentage of the extinct species is not as great as the 75 percent of the Sinanthropus group at Chou-k'ou-tien, however, it surpasses the 43 percent of the Sjara-Ossa-Gol bed at Ordos and 28 percent of the lower bed of Afontova along the River Yenisei. Namely, the fauna belongs approximately to the range from the middle Diluvium to the late Diluvium.

In the list of mollusks, five species marked with asterisks are said not to be known as the living species.

The climatic conditions of 52 mammalian fossils from the Ku-hsiang-t'un formation are as follows (numbers in parentheses indicate specific numbers of specimen):

Climate	Percentage of living species	Percentage of extinct species	Total (%)
Species which lived under approximately the same climatic condition with the present time	30 (16)	28 (15)	58
Boreal type	7 (4)	19 (10)	26
Tropical type	1 (1)	11 (6)	12

That is, among the living species, the species which indicate the present climatic conditions of north Manchuria are abundant. If the extinct species are included, the percentage become 58, so it is probable that the climate of that age was not very different from the present. The species of the frigid type which migrated southward and those of the tropical type which migrated northward exist together. It is inferred that the yearly variation between the summer and winter seasons was conspicuous. However, species which live in more frigid areas, such as Rangifer and Ovibos, were not found at all. This can be said not only of Ku-hsiang-t'un but of all Manchuria. The southern limit of distribution of mammoth is Ta-lien, 39° north latitude, while in the prewar Japanese territory of south Sakhalin, 46° north latitude [28].

No human skeletons were found; however, some bone and stone implements have been found. Because of the conditions of the locality, stone implements are very rare; however, those of racloir type have been found. The lithic characters are basalt, quartz, chert, and other rocks. Artificially worked bone implements are rather abundant, and many implements such as spear heads, chisels, and kitchen knives have been found. Besides them, bone pieces cut in about the same length, bone pieces with traces that they were bound by strings, a rhinoceros skull with hammer impressions, and some kind of deer-bone implement were unearthed. Coarse and fine implements are mixed with fine small implements. The degree of culture generally corresponds with that of Mousterian-Aurignacian in western Europe. However, it is also said that this culture, together with that of Djalainor, may be correlated with the Siberian paleolithic culture [37]. At least, the abundance of bone implements is a remarkable feature. It is considered that the remains of human culture may belong to loess-camp. Some charcoal lumps were found, so it is noted that fire was used by paleolithic men. Ponosoff collected some paleolithic stone implements in the upper part of the upper bed and he correlated them with Magdalenian. However, according to Teilhard de Chardin and Wei-chung Pei, the implements which were considered paleolithic by Tokunaga and Naora belong to the mesolithic on the whole. However, in this case, the frequency of stone implements in the Ku-hsiang-t'un formation and in the Wen-chuan-ho bed is not yet distinct. A splendid stone implement collected in trench 32 by the writer and others in the course of the digging in 1938 was of Mousterian type; this stone implement was collected at the lowest part of the upper bed.

The Ku-hsiang-t'un formation is rich in fossils and paleolithic remains, and it is a valuable formation which may be correlated with the Ordos. In 1943, the writer [28] correlated these two localities as follows:

Manchuria	Ordos
Wen-chuan-ho bed	Black earth - Culture of black-earth stage
Upper Ku-hsiang-t'un formation	Sjara-Osso-Gol - Culture of mesolithic type (Azilian-type culture)
Lower Ku-hsiang-t'un formation	Lower part of the Sjara-Osso-Gol bed - Culture of Moustero-Aurignacian type
(?)	Ma-lan loess - Moustero-Aurignacian

In general, in a chronological correlation with European cultures, the paleolithic remains from north Manchuria to eastern Siberia show features ranging from Mousterian to Magdalenian, and they belong to an age with the Würm glacier stage as the center.

It is inferred that the Ku-hsiang-t'un formation is rather extensively distributed in the drainage basin of the Sung-hua Chiang, and the following fossil localities are known:

1. T'ao-lai-chao, Chi-lin [Kirin] province: mammoth.

2. San-k'o-shu, northeast of Harbin: mammoth, Bison, Bubalus, Equus.

3. "Tanolin" tunnel, Chi-tao-kou, Pin-chiang [Pinkiang] province: mammoth.

4. Mu-leng coal mine, Pin-chiang province: artificially worked deer antler (Cervus elaphus?) from the surface soil in the upper bed of the mine.

5. In the vicinity of Hei-ho [Ai-hun]: skull of Bison from the sands along a river.

6. Niu-la-cheng-tzu, Pin-chiang province, adjoining village west of Ku-hsiang-t'un: mammoth.

7. River floor of Sung-hua Chiang at a suburb of Harbin: mammoth.

8. In the vicinity of Fularki station [Fu-la-erh-chi] along the Nen Chiang, Hei-lung-chiang province: Rhinoceros antiquitatis.

9. Tsitsihar [Ch'i-ch'i-ha-erh], Hei-lung-chiang province: molar of mammoth unearthed when the Tsitsihar castle was constructed about 300 years ago and formerly possessed by the Li family. (Now it is in the National Science Museum in Tokyo).

10. Foot of Ta-hsing-an-ling Shan-mo, Hsing-an province: Poephagus grunniens (Przew.).

11. Hai-lum.

12. K'o-shan and Pai-ch'üan: splendid tusks, skull, mandible, and other bones of mammoth.

13. Along the La-lin Ho, south of Harbin: mammoth.

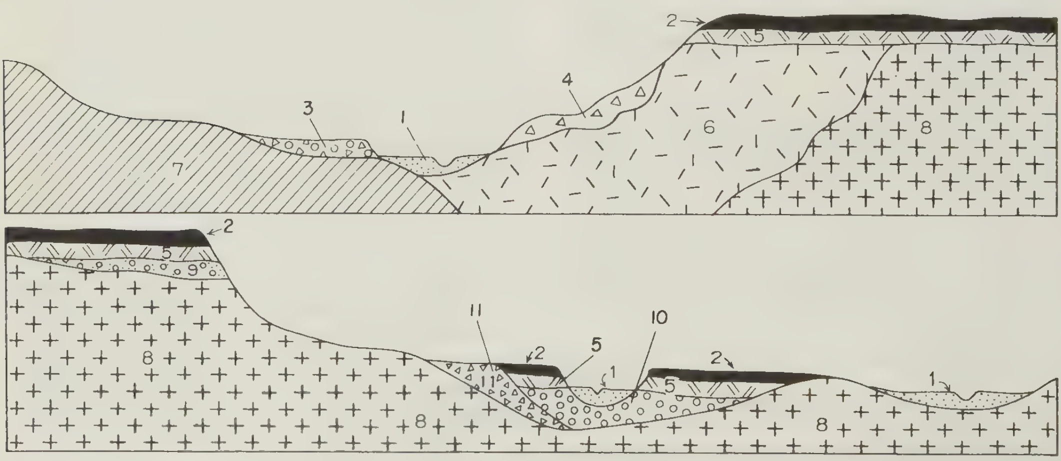


FIGURE 6. Pleistocene in Pin-Chiang, San-Chiang, and Chi-Lin provinces (Taleyama and Asano, 1937)
(1) alluvium, (2) soil above basalt, (3) terrace deposits or fanglomerate, (4) talus deposits, (5) basalt, (6) andesite, (7) Mesozoic sediments, (8) granite, (9) sand and gravel below mesa basalt (Tertiary), (10) sand and gravel below lower level basalt, and (11) zone of decomposed granite.

14. In the vicinity of Ningguda [Ning-an] along the A-shi Ho.

15. In the vicinity of Man-kou [Tien-ts'ao-kang]: Gazella.

16. East of Füyü and Ta-lai: mammoth.

17. Iyasaka village and Ta-ku-tung in the vicinity of Chu-lien: mammoth.

18. Ho-li-kang [Hao-li] coal field.

19. Shang-i-hsiang and Ssu-tung in the vicinity of Yen-chi, Chien-tao province: mammoth.

Ssu-tung is located on the T'u-men Chiang and opposite Kamisanbo [Sangsambong] in Korea. In both these localities, loesslike clay, which is equivalent to the Ku-hsiang-t'un formation, is developed. At the digging in 1935, Tamezō Mori and Fu-cheng Chao collected the following fossils from the yellow-clay bed which underlies the yellowish-clay bed at Ta-ma-lu-kou, Shang-i-hsiang, most of which are fragments [35]: 1) Cervus elaphus L., C. sp., Equus sp., Atelodus sp., and Mammuthus primigenius (Blum.).

DJALAINOR [DARINOR] FORMATION

The Djalainor coal mine in Hsin-gan province is north of Lake Djalai [Dalai Nor or Hu-lun Ch'in], and it is situated at a corner of the Mongolian facies.

According to Tolmatchev's report in 1929, a columnar section of a trench in the Djalainor coal mine is as follows, in a descending order [39]:

	meters
1. Surface-soil bed of humus	3.5
2. Dried-sand bed	2
3. Compact-mud bed	1
4. Sand bed	2
5. Perpetually frozen mud bed	1
6. Perpetually frozen small-grained gravel bed	1
7. Claylike-shale bed	1
Unconformity	
8. Coal seam	6.5
9. Gray clayey-earth bed	?

The first seven beds belong to the Quaternary period, and a skull of Rhinoceros antiquitatis, a tusk of mammoth, a skull of Bison, and others were collected from fifth to seventh beds. Artificially worked deer antlers were found in the upper part of the frozen bed. Some of the deer antlers have been formed like a square hammer head with a rectangular hole. A similar implement was collected by Ch'ih-feng, and sculptured vertebral bone of Rhinoceros antiquitatis was collected in a sand dune near Hailar [Hai-la-erh].

In 1933, Djalainor skull I was found in the gray-sand bed with gravel which is situated between the surface soil and the coal seam. Then in 1943 Yoshirō Yuda found skull II. These skulls were studied by Endō [6]. In September 1944, Endō and Pei surveyed the field and collected the so-called skull III, namely, the left half of a mandible, right ulna, left ulna, and a fragment of a rib together with several mammalian fossils and about 10 thousand small implements. According to Endō, the section of Nan-mei-kou open mine is as follows, in a descending order:

1. Surface soil	5-10 cm
2. Peat bed	10-30 cm
3. Yellowish-brown gravel bed containing fresh-water bivalve shell	15-30 cm
4. Grayish-sand bed	1-2 m
5. Gray to yellowish-gray sand bed with gravel	2-4 m
6. Gravel bed	1 m
7. Coal seam	[Ed.: ?]

It is said that skull I was found in the fifth bed and it may correspond to Tolmatchev's sixth bed. Skull II was collected at the third colliery; the section in this vicinity is similar to that of Nan-mei-kou, and it is said that the skull II was unearthed from the fine sands with gravel, about 10 m below the surface. Among the mammalian fossils collected by Endō and others were Rhinoceros antiquitatis Blum, mammoth, and Equus przewalskyi Polliakoff.

Skull I probably belonged to a middle-aged female, while skull II belonged to a middle-aged male. The breadth of orbit is rather large and the breadth of foramen magnum is relatively narrow. The basion-bregma height, maximum length, an maximum breadth are 147 mm, 177 mm, and 137 mm, respectively. The head had suffered some deformation, that is, it shows that it had been strongly pressed on the forehead by some plate or fur [hide] during life.

Many small implements are abundantly scattered on the terraces on the west side of the River Noutomaya [sic], which runs between Lake Djalai and Djalainor mine. These implements are arrow heads, spear heads, knives, flakes, grattoirs [scrapers], and nuclei [cores] which were made of agate, obsidian, and vein quartz. According to Pei, these implements belong to the Lin-hsi-type culture and indicate mesolithic age. Around the Nan-mei-kou open mine, some small stone implements of the Lin-hsi-type are found, and, besides them, one bifacial implement of certain paleolithic appearance was formerly collected.

According to Hōichi Yoshizawa and Jun'ichi

Iwai [42], the formation underlying the alluvial deposits of the River Hailar [Hai-la-erh Ho] and the sandy-clay bed in the lowland north of Lake Djalai belong to the Hailar formation and can be correlated with the Djalainor formation. Mammoth and Bison were found during the construction of bridge piers in the River Hailar north of Hailar.

The Hulunbuyer formation in the Hulunbuyer plain is composed of eolian sands and it consists of fine sands of quartz and feldspar. Though the plain shows a rolling topography on a large scale, it might have been one kind of sand dunes at the time of its deposition. It alternates with the Hailar formation of lacustrine facies. A river-terrace formation crops out at 5 to 19 m above the present alluvial plain and it consists of gravels.

East of Hailar [Hai-la-erh]

Surface soil	1. 1 m
Yellowish-brown to yellowish-gray fine sands	32. 0 m
Arenaceous clay	34. 0 m
Gravel-bearing blue clay	40. 5 m
Gravel	46. 8 m

North of Hailar (Ta-liang-shang)

Brown sediment	1. 0 m
Light-brown clay	5. 0 m
Grayish-white fine sand	9. 0 m
Light-brown clay mixed with sand	13. 0 m
Light-brown find sand	15. 0 m
Brown fine gravel	19. 0 m
Coarse sand	20. 0 m
Light-brown fine sand	22. 0 m
Coarse sand	31. 0 m
Gravel	32. 0 m
Light-brown sand	37. 0 m
Light-brown coarse sand	38. 2 m

5 km North of "Oronur" Northeast of Kanchur [Kan-chu-erh-miao]

Surface soil	0. 9 m
Grayish-white clay	4. 9 m
Blue clay mixed with sand	12. 5 m
Black clay	17. 0 m
Fine gravel	18. 3 m
Brown clay	?

In the San-ho district, the surface soil, ± 1 m thick, is underlain by a gravel bed ± 2 m thick, alternation of clay and sand, or alternation of gravel and clay, from which mammoth and other fossils were unearthed.

According to Udea and Sasakura [40], an eolian sand bed is extensively developed in the area north of Wu-tan-ch'ang, Hsing-an-hsi [west Hsingan] province, and it shows the Mongolian facies. A tableland 20 to 40 m above the adjoining alluvial plain is distributed along the south bank of the River Shara-muren [Hsi-la-mu-lun Ho]. Remarkable eolian sand, 60 or 70 m thick, is extensively distributed near Lin-hsi, in the area between Ta-pan-shan and Lin-tung and in the Chakhar [Chahar] district [just north of Lin-hsi] as well as in the area between Hsi-ching-peng and Tarinor [Ta-erh Hu]. The eolian sand is developed in the meridional direction along the margin of Ta-hsing-an-ling Shan Mo from east of Tarinor. A white-clay bed, several meters thick, is developed in the lower part of the basin 100 m southeast of Ta-wang-wiao on the southeastern shore of Tarinor ("nor" means lake in the Mongolian language); from the bed the following fossils have been found: Lymnaea (Radix) teilhardi (Ping), Gyraulus chiliensis (Ping), and Pisidium sp. In 1931, Isao Matsuzawa, Namio Egami, and others collected fresh-water shells from the brown-sand bed (overlain by the Ma-lan loess) on the south bank of the River Balga in the vicinity of Ulan-hosho and on the east bank of the River Nühüs in the neighborhood of Zakustai-Süme. According to Kōichi Suzuki, the following fossils are among them: Lymnaea (Galba) pervia von Martens, L. (Radix) auricularia obriquata von Martens, Anisius (Gyraulus) gredleri ("Bielz" Gredler), and A. (Segmentin) nitidellus von Martens.

The above fossiliferous bed is also developed in the sand-dune zone, 20 km south of Tarinor, and its succession is as follows, in a descending order:

Surface soil and sand	60 cm
Brown sand	30 cm
Black sand	15 cm
White fossiliferous clay	20 cm
Sand	[Ed. :?]

The result of boring at Tarinor (Djalainor) city is as follows:

Surface soil and sand Blackish-brown surface soil	5 m
Light-brown fine sand Small gravel	5 m
Gravel Blue clay	5 m
Reddish-brown arenaceous clay mixed with gravel	5 m
Light-bluish clay	5 m
Reddish-brown fine sand	5 m
Light-blue clay	5 m
Brown fine sand	5 m
Dark-brown clay mixed with earth and sand	5 m
Hard-textured clay	[Ed. :?]

TERRACE-GRAVEL BEDS AND BASALT PLATEAUS

Terrace-gravel beds are distributed everywhere in the Ta-hsing-an-ling Shan Mo, Hsiao-hsing-an-ling Shan Mo, and Chang-pai Shan, and

basaltic plateaus are also extensively developed. These piedmont facies pass gradually into the Manchurian facies.

Diluvial terraces, 50 m above the adjacent plain, are distributed along the Hei-lung Chiang [Amur river] on the northern slope of the Hsiao-hsing-an-ling Shan Mo from the River Fupiehlahe [Fa-pieh-la Ho] upstream from Hei-ho [Ai-hun] to the Wu-Yün district. A succession of gravel and clay is distributed along the Pei-hei line [12]. A gravel bed is developed on the northern slope [of Hsiao-hsing-an-ling Shan Mo] while a clay bed crops out thick on the southern slope and is divided into the lower gravel bed (10 to 20 m) and the upper clay bed. Gravels as large as a human head are mixed in the area west of Aigun [Ai-hun]. Gravels of the gravel bed along the river Chan Ho and Ko-erh-fen Ho in the west of the Nan-pei Ho [USGS Ed. : Chan Ho is east of Nan-pei Ho] consist of chert, radiolarian chert, quartzite, graywacke, and clayslate. It is said that the upper clay bed is developed under the alluvial deposits along the Hu-yü-erh Ho [Wu-yü-erh Ho] and Na-mu-Ho [Nan-yeng-Ho] and their tributaries, and it is estimated to 60 or 70 m thick. It contains bentonite at Lung-an [Lung-men] and Pei-an while it also includes lignite at Tai-an.

In the district of Pai-ch'üan, Hai-lun, and Sui-hua, the lower part consists of a sandy bed with much crossbedding, while the upper part is composed of a clay bed with bentonite and its thickness is estimated to be 60 or 70 m, as seen along the Pin-pei line. That is, the formation in this district is distinctly a prolongation of the Ku-hsiang-t'un formation.

Terrace gravel beds are also distributed along the Nen Chiang.

Basaltic plateaus, 20 to 40 m above the adjacent plain, are distributed along the Kan Ho and No-min Ho on the eastern slope of Ta-hsing-an-ling Shan Mo. These plateaus and diluvial plateaus are rather difficult to distinguish topographically.

Thick alluvial deposits of fluvial origin are developed along the Hei-lung Chiang [Amur river] and Nen Chiang and they consist of arenaceous clay, sand, and gravel. A gravel bed of several meters thick has been found 5 m below the earth's surface in Hei-ho [Ai-tun] city.

A vast triangular area which is surrounded by the Ussuri river [Wu-su-li Chiang] and the Sung-hua Chiang with Khabarovsk as its apex -- namely, in the downstream composed of thick alluvial deposits and the ground is subsiding. The northeastern prolongation of the Ku-hsiang-t'un formation is found here and there, mostly forming terraces. An example is found in the area between Harbin and Fu-chin. A gravel bed, 20 m thick is found in the vicinity of I-lan [3]. A succession of light yellowish-brown arenaceous clay and clay is developed at Fu-chin. Mammoth was unearthed at Ta-ku-tun [near Fu-chin]. A gravel bed is also found in the Ho-kang coal mine [near Hao-li]. A gravel bed is most typically developed in the vicinity of Tai-p'ing-chen along the Wo-ken Ho. A gravel bed is also distributed in the vicinity of Mi-shan south of Tung-an and in the neighborhood of Po-li. In the vicinity of Pin-yang [P'ing-yang-chen], a gravel bed is developed under the basaltic lava flow in association with basaltic plateaus. Terraces composed of gravel beds more than 10 m in thickness are distributed in the districts of Mu-tan-chiang, Tung-ning and Tung-king-chang [Tung-ching-ch'ang-chieh]. There are two kinds of gravel beds. One of them is the gravel bed underlying the plateau basalt and the other is that underlying the new basalt flows which occupy the present river valleys. It is considered that the latter belongs to the Diluvium series. According to Okada and Nishida [24], the Diluvium series in the vicinity of Tu-men-tzu, Chien-tao province, is a terrace deposit and it consists of gravel and clay. It is distinguished from the Tertiary gravel bed by the basalt pebbles. Most of the pebbles are composed of basalt, and it contains secondary placer gold which was washed out from the gold-bearing Tertiary system.

Basaltic plateaus in Mu-tan-chiang and T'ung-hua provinces cover a vast area. In the district from Chi-lin [Kirin] province to T'ung-hua province in the upper stream of the second Sung-hua Chiang, diatom earth is distributed along the inclined slope of each river head of each small river which dissected the low tableland consisting of basalt. According to Nishida [21], the diatom earth was formed in the marshes on the basaltic plateaus, and it is intercalated between gravel bed and clay bed; it is estimated to be 1 to 2. 5 m thick. The following species of diatoms are found: 1) Melosira ambigus (Grun) O. Mull. , 2) Diatoma anceps (Ehr.), 3) Fragilaria virescens Ralfs. , 4) Navicula koreana Skortzov, 5) N. mutica Kutz. , 6) Pinnularia distinguenda Cleve. , 7) P. brevicostata Cleve. , 8) Synedra vaucheriae Kutz. var. truncata (Grev.) Grun.

The surface soil in north Manchuria is different from that of south Manchuria: it is pitch black to grayish black and can be divided into black soil and alkali soil. The black soil covers the hills of the Diluvial series and forms the so-called black-earth zone. It is a tschernosem. It is distributed in the area of the diluvial hills in the vicinity of No-ho, T'ai-an, K'o-shan, Pei-an, and Lung-chen [Lung-men] north of Ning-nien as well as the eastern marginal hills in the Hai-lun Pai-chüan district. The thickness is estimated to be 0. 5 to 2 m. The surface soil in the area from the steppe lying in the Tsitaihar [Ch'i-ch'i-ha-erh] district to the drainage basin of the Hu-yü-erh-Ho [Wu-yü-erh Ho] is composed of leached tschernosem and its thickness is

estimated to be 0.3 to 2 m. The alkali soil consists of serozem [USGS Ed.: ?sierozem] and it is distributed as far as central Manchuria and is particularly remarkable in the areas from the vicinity of T'ai-lai and Chen-tung to the area west of T'ao-nan, the district of K'ai-t'ung, and the vicinity of Chang-u [Chan-yu-chen], and T'u-chüan. In the sand-dune districts, alkali-soda is exuded on the earth surface in the dry season.

PROBLEMS OF THE GLACIAL AGE IN MANCHURIA

Kazui Fujita [9] mentioned the following noticeable fact in his report of Ta-hsing-an-ling Shan Mo research work. A rock-detritus bed which consists of fist-sized breccias is found at 200 to 300 m above the adjacent plain (1,000 m average elevation above sea level), and these breccias are frozen by pure ice. He maintained that this detritus was produced under a very cold climate in which the daily and yearly ranges of temperature were very large and vegetation could not grow. The present flora might have migrated in the successive temperate period.

Permanently frozen beds which predominate in Siberia, might be formed under climatic conditions similar to the present in Siberia, where the winter is long with very severe cold and scanty rainfall and the temperature in summer is relatively low. However, it is inferred that there was an age of severe cold climate in the past when the lower limit of the frozen bed was lowered as much as several hundred meters.

Fujita opposed Plaetschke's view that the permanently frozen bed and the glacial topography of the northern Ta-hsing-an-ling Shan Mo are associated. Fujita maintained that the permanently frozen bed was formed in an arid high-latitude zone, while the mountain glaciers in east Siberia (that may be related to the glaciated stages of P'ai-t'ou-shan and Kan-po-ho [14]) were formed in a period when the air temperatures were rising, which may not have always coincided with the most flourishing stage of the permanently frozen bed. Fujita's opinion is similar to Simpson's view. Though there may be some differences between the glacial ages of north Europe and of north Manchuria, the extent of the difference has not yet been determined. If the detritus bed, that is, the permanently frozen bed, is prolonged toward the west, it may be correlatable with the frozen bed in Transbaikalia or in the Djalainor district. If the Djalainor formation, the mammoth-bearing frozen bed at Peryozovka, and the fossil bed at Afontova (Magdalenian) correspond with the severe cold stage of these frozen beds, then, the Würm glacier stage in north Europe may correspond with the stage of permanently frozen bed in north Manchuria. If this is true, glaciers may not have developed in north Manchuria. This problem may be settled to some extent by the correlation of the Wisconsin glacial stage throughout Kamchatka, Alaska, and Canada.

Cirques on P'ai-t'ou Shan (each cirque on Taishō peak, Matengu and Sōgan), U-shaped valleys 2,000 m above the timber line, a cirque on Mt. Minami Potai, and the cirque group of Kanbo peak are found in very scanty snowfall districts of the present time. According to Asano [2], the P'ai-t'ou glacier stage is considered post-pumice eruption of P'si-t'ou Shan and pre-mud lava eruption. The scantiness of Pinus pumila on P'ai-t'ou Shan may be due to the eruption of the mud lava. The formation of the caldera, the formation of cirques, the migration of P. pumila, the eruption of mud lava, and the recession of P. pumila may have occurred in this order. It is regrettable that the relation between the P'ai-t'ou glacial stage and the Ku-hsiang-t'un formation has not yet been determined. This problem cannot be solved by the study of the relation between the plateau basalt and the Kamisanbō clay bed, which is equivalent to the Ku-hsiang-t'un formation and distributed in Kamisanbō [Sangsambong], Tung-kwan-chen [Tonggwan-dong], Yen-chi, Lung-ching-chieh, and vicinity. We feel acutely the poverty of data in the Siberian side.

CONCLUSION

The Quaternary system in Manchuria is roughly divided into three divisions, namely, the north Chinese facies (loess facies), the Mongolian facies (eolian facies), and the Manchurian facies (flood-plain lacustrine facies). The first facies is distributed in the districts of Liao-hsi and Liao-tung with Jehol as its center. The second facies is mainly developed in the area west of the western slope of Ta-hsing-an-ling Shan Mo while the third facies is distributed mainly along the Sung-hua Chiang with the Manchurian plain as its distributive center. The trend of the boundary line between the north Chinese facies and the Manchurian facies is approximately north-northeast, which is a line connecting Cheng-chia-t'un and K'ai-yuan and it corresponds to the Hei-liao divide. A piedmont facies is developed in the mountain district, and basaltic plateaus are also extensively distributed.

Types of the north Chinese facies, Mongolian facies, and Manchurian facies are the Liao-ho plain group, Djalainor formation, and Ku-hsiang-t'un formation, respectively.

Chronology of the Quaternary system in Manchuria approximately corresponds with that of north China and it is divided into three sedimentation stages: Chou-k'ou-tien stage in the lower Diluvium, the Ma-lan stage in the upper Diluvium, and the black-earth stage in the Alluvium in an ascending order. The Ma-lan series is developed better than in north China, while the Chou-k'ou-tien series is not so remarkable. The

Liao-tung stage, which is equivalent to the Ching-shui stage in north China, is found between the above-mentioned two stages [Chou-k'ou-tien and Ma-lan] and was a remarkable erosion stage. The so-called Liao-tung peneplain was formed in this stage. The flows of plateau basalt may have been in this stage. Moreover, the Liao-ho erosion stage intervened between the Jehol loess, which corresponds with the Ma-lan loess, and the redeposited loess (equivalent to the Ku-hsiang-t'un formation). The erosion stage of the present time is the Sung-hua Chiang stage which is correlatable with the Pan-chiao stage in north China. The erosion stage between the Ma-lan stage and black-earth stage (the Wen-chuan-ho stage) is the Wa-pen-yao stage or the Lao-ha stage.

Fissure deposits of the Chou-k'ou-tien type are found in the Hsiao-sheng-shui-sen group or the Niu-hsin-shan group, and the lower part of the Niu-hsin-shan group is correlatable with the *Sinanthropus* group at Chou-k'ou-tien.

The complete formation of the Hei-liao divide was in the Lao-ho stage. Its slow upheaval movement may correspond with the terrace movement of Du_1 plane on the Japanese island, and it seems that a tectonic movement which divided the Manchurian facies and north Chinese facies was in progress from the Ching-shui stage. The Hei-liao divide is related to the tilting movement of the Korean peninsula.

The fossil facies of the Ku-hsiang-t'un formation is rich and contains plants, Mollusca, Insecta, Pisces, Reptilia, Aves, Mammalia, and others. Percentage of extinct Mammalia is less than 75 of the *Sinanthropus* group in Chou-k'ou-tein, but it surpasses 43 of the Sjara-Osso-Gol in Ordos; it indicates an age of approximately middle to later Diluvium. Rhinoceros, bison, wild horse, and deer are most abundant, and the appearances of *Struthio*, *Castor*, *Gazella*, *Bubalus*, and *Camelus* are noticeable. *Rangifer* has not been found.

Culture of stone implements of the Ku-hsiang-t'un formation shows the facies from the Mousterian to the Magdalenian, and it was developed with the Würm glacier stage as the center. However, some geologists consider that it is a mesolithic culture.

Three human skulls (the Djalainor man) were found from the Djalainor formation. Stone implements which were unearthed with the skulls are small sized; they are regarded as belonging to the mesolithic culture.

It is considered that there is some relation between the detritus bed--permanently frozen bed on the Ta-hsing-an-ling Shan Mo--and the Würm glacier stage in Europe or the Wisconsin glacier stage in North America. The problems of the relation between the permanently frozen bed and the Djalainor formation, or the Ku-hsiang-t'un formation, must be solved in future.

REFERENCES

1. Aoji, Otoji, GEOLOGIC MAP OF MANCHURIA AND ITS EXPLANATORY TEXT, TA-KU-SHAN SHEET: Manchuria, Geol. Inst., 1925 (in Japanese).

2. Asano, Gorō, SEVERAL FACTS FOUND BY PAI-TOU-SHAN EXPEDITION IN 1942-43: Mineral. and Geology, v. 1, 1947 (in Japanese).

3. Asano, Gorō, and Toshi Takeyama, GEOLOGY AND GEOGRAPHY IN THE EASTERN PART OF MANCHURIA: Manchuria, Geol. Inst., 1937 (in Japanese).

4. Barbour, G. B., PHYSIOLOGY OF JEHOL: Geol. Soc. America, Bull., v. 46, 1935.

5. Endō, Riuji, REPORT OF RESEARCH WORK AT A FOSSIL LOCALITY AT KU-HSIANG-T'UN NEAR HARBIN, PING-CHING PROVINCE: Manchurian Association for Preservation of Historic Sites and Natural Monuments, 1942 (in Japanese).

6. __________, REPORT OF THE SEARCHING WORKS OF THE DJALAINOR HUMAN SKELETON: Cent. Nat. Museum Manchoukuo, Current Rev., 1944, no. 23 (in Japanese).

7. __________, ON THE DJALAINOR SKULLS: Jap. Acad., Proc., v. 21, no. 9, 1945.

8. __________, ON THE DJALAINOR HUMAN SKELETON: Kagaku, v. 19, no. 9, 1949 (in Japanese).

9. Fujita, Kazuo, A CONSIDERATION OF THE CLIMATIC CHANGES IN EASTERN ASIA: Mineral. and Geology, v. 1, no. 3, 1947 (in Japanese).

10. Hanai, Jūji, SO-CALLED LOW-LEVEL PENEPLAIN DEVELOPED ON THE LIAO-TUNG PENINSULA AND ITS SEVERAL FEATURES: Geogr. Rev. Japan, v. 4, no. 10, 1928 (in Japanese).

11. Haraguchi, Kuma, REPORT OF GEOLOGICAL SURVEY AT THE FIRST PROPOSED DAM SITE OF LIAO HO RESERVOIR: Manchuria, Geol. Inst., Rept. no. 96, 1939 (in Japanese).

12. Horinouchi, Kazuo, Hikoji Morita, and Shirō Yamaguchi, GEOLOGY AND GEOGRAPHY IN THE NORTHERN PART OF MANCHURIA: Manchuria, Geol. Inst. 1937 (in Japanese).

13. Imamura, Zenkyō, and Teijirō Tsuchida, GEOMORPHICAL CONSIDERATIONS IN THE NORTHERN PART OF KWAN-TUNG PROVINCE: Manchuria, Educational Inst., Rept. no. 4, 1935 (in Japanese).

14. Kano, Tadao, ON THE GLACIATED TOPOGRAPHY IN THE NORTHEASTERN MOUNTAINLAND IN KOREA: Geogr. Rev. Japan, v. 13, no. 12, 1937 (in Japanese).

15. Kobayashi, Teiichi, A CONSIDERATION OF THE RELATION BETWEEN THE HISTORY OF THE TOPOGRAPHICAL DEVELOPMENT OF THE KOREAN PENINSULA AND THE CENOZOIC GEOLOGICAL HISTORY: Geogr. Rev. Japan, v. 7, nos. 7-9, 1931 (in Japanese).

16. Kusamitsu, Shigeru, ON THE TOPOGRAPHY IN THE VICINITY OF PEI-PIAO AND THE LATER DEPOSITS: Geol. Soc. Manchuria, Bull., 1942, no. 3 (in Japanese).

17. Licent, E., and P. Teilhard de Chardin, GEOLOGICAL OBSERVATIONS IN NORTHERN MANCHURIA: Geology China, Bull., v. 9, 1930.

18. Loukashkin, A. S., SOME OBSERVATIONS ON THE REMAINS OF A PLEISTOCENE FAUNA OF THE PALEOLITHIC AGE IN NORTHERN MANCHURIA: Early Man, 1937.

19. Niinomy, Kunitarō, PHYSIOGRAPHIC SYSTEM IN MANCHURIA (In: Manchuria, compendium of geography of Japan): Tokyo, 1930 (in Japanese).

20. Nishida, Shōichi, REPORT OF RESEARCH WORK AT HSING-CHING HOT SPRING IN CHIN-CHOU PROVINCE: Manchuria, Geol. Inst., Rept. no. 95, 1939 (in Japanese).

21. __________, MODE OF OCCURRENCE OF THE DIATOM EARTH ALONG THE SECOND SUNG-HUA CHIANG: Manchuria, Geol. Inst., Rept. no. 102, 1941 (in Japanese).

22. Noda, Mitsuo, OUTLINE OF GEOLOGY IN THE VICINITY OF CHANG-TU: Talien, Manchuria, n.d. (in Japanese).

23. Okada, Naoe, PRE-HISTORICAL RESEARCHES IN KU-HSIANG-T'UN: Manchokou, Inst. Sci. Res., Mem., v. 3, no. 1, 1939 (in Japanese).

24. Okada, Shigemitsu, and Shōichi Nishida, GOLD-BEARING TERTIARY FORMATION, DISTRIBUTED IN THE VICINITY OF TU-MEN-TZU, CHIEN-TAO PROVINCE: Manchoukuo, Geol. Inst., Rept. no. 98, 1940 (in Japanese).

25. Ponosoff, V. V., STONE IMPLEMENTS FROM KU-HSIANG-T'UN: Manchoukuo, Inst. Sci. Res., Bull., v. 1, no. 3, 1937.

26. Saitō, Rinji, REPORT OF RESEARCH WORK OF TANG-KANG-TZU HOT SPRING: Manchuria, Geol. Inst., Rept. no. 95, 1939 (in Japanese).

27. __________, GENERAL OBSERVATIONS ON GEOLOGY IN MANCHURIA: Manchuria, Geol. Inst., Rept. no. 100, 1940 (in Japanese).

28. Shikama, Tokio, PLEISTOCENE PROBLEMS IN JAPAN AND VICINITY, SOME TENTATIVE CONSIDERATIONS IN PALEOMAMMALOGY: Cent. Nat. Mus. Manchoukuo, Bull., 1943, (in Japanese with English abs.).

29. __________, LATE CENOZOIC FORMATIONS IN MANCHURIA: Mineral. and Geology. v. 3, no. 5, 1950 (in Japanese).

30. __________, NOTES ON THE CHRONOLOGY OF JAPANESE QUATERNARY: Geol. Soc. Japan, Jour., v. 56, no. 659, 1950 (in Japanese).

31. Suzuki, Kōichi, SOME FOSSIL MOLLUSCA FROM KU-HSIANG-T'UN, NEAR HARBIN, MANCHOUKUO: Geol. Soc. Japan, Jour., v. 42, no. 499, 1935.

32. Tada, Fumio, GEOGRAPHY OF JEHOL: 1st. Sci. Exped. to Manchoukuo, Rept., sec. 3, Tokyo, 1937 (in Japanese with English abs.).

33. Takai, Fuyuji, FOSSIL ELEPHANTS FROM THE HAO-KANG AND PEI-PIAO COAL FIELDS, MANCHOUKUO: Manchuria, Geol. Inst., Bull., 1941, no. 101.

34. Teilhard de Chardin, P., EARLY MAN IN CHINA: Inst. Geo-biologie (Peking), Rept. no. 7, 1941.

35. Tokunaga, Shigeyasu, and Tamezō Mori, REPORT OF EXCAVATION AT DO-KANTIN, THE BANK OF THE TUMEN RIVER, KOREA: 1st. Sci. Exped. to Manchoukou, Rept., sec. 2, pt. 4, Tokyo, 1933 (in Japanese with English abs.).

36. Tokunaga, Shigeyasu, and Nobuo Naora, REPORT ON THE FIRST EXCAVATION AT HO-CHIA-KOU, KU-HSIANG-T'UN KIRIN, MANCHOUKUO: 1st. Sci. Exped. to Manchoukuo, Rept., sec. 2, pt. 1, Tokyo, 1934 (in Japanese with English abs.).

37. Tokunaga, Shigeyasu, and Nobuo Naora, PALEOLITHIC ARTIFACTS EXCAVATED AT HO-CHIA-KOU IN KU-HSIANG-T'UN, MANCHOUKUO: 1st Sci. Exped. to Manchoukuo, Rept., sec. 6, Tokyo, 1936 (in Japanese with English Abs.).

38. ________, FOSSIL REMAINS EXCAVATED AT KU HSIANG-T'UN NEAR HARBIN, MANCHOUKUO: 1st Sci. Exped. to Manchoukuo, Rept., sec. 2, pt. 4, Tokyo, 1939 (in Japanese with English abs.).

39. Tolmatchev, V. J., SUR LE PALEOLITHIQUE DE LA MANCHURIE [ON THE PALEOLITHIC OF MANCHURIA]: Eurasia Septentionalis Antiqua, v. 4, [USGS Ed.: 1929].

40. Ueda, Fusao, and Masao Sasakura, GEOLOGY AND GEOGRAPHY IN THE SOUTHWESTERN PART OF MANCHURIA: Manchuria, Geol. Inst., 1937 (in Japanese).

41. Yamamoto, Sōki, LATEST GEOLOGICAL HISTORY OF MANCHURIA: Kagaku, v. 18, no. 1, 1948 (in Japanese).

42. Yoshizawa, Hajime, and Jun'ichi Iwai, GEOLOGY AND GEOGRAPHY IN THE NORTHWESTERN PART OF MANCHURIA: Manchuria, Geol. Inst., 1937 (in Japanese).

CONTEMPORARY MOVEMENTS IN THE EARTH'S CRUST[1]

by

Yu. A. Meshcheryakov[2]

• *translated by Anita Navon* •

ABSTRACT

Increased accuracy and volume of geodetic investigation, particularly precise repeated leveling, has made possible the study of secular land movements, the slow uplift and subsidence of the lithosphere. Many nations have engaged in level-measuring surveys which have resulted in the compilation of maps of contemporary crustal movements. Although many geodesists and geologists maintain that only certain parts of the earth's crust are mobile, there is not a single area of any consequence in which secular movements are absent. Contemporary movements, varying in direction and intensity, occur in mountainous regions, plains, and sea bottoms. These movements influence river patterns, shoreline configurations, and landscape forms in general. With increased precision and number of engineering projects, the consideration of secular movements becomes a necessary element in long-term planning of complex construction such as ports, pipelines, canals, irrigation systems, and hydroelectric stations. --G. E. Denegar.

INTRODUCTION

Of the concentric covers of the earth, the atmosphere, hydrosphere, and lithosphere, the earth's crust (lithosphere) is sharply distinguished, at first glance, by its immobility. Oceans and seas are in constant ferment, air masses are continually moving, and only the surface of the earth, it seems, remains at rest. But it is enough to recall that on an average of every 5 minutes seismic stations are registering an earthquake on the globe, and the idea of the immobility of the earth's crust is shaken. Striking evidence of the movement of the lithosphere is seen in destructive earthquakes.

With the rapid, or seismic, movements of the crust exist movements of another type: slow risings and sinkings of the earth's surface completely imperceptible to man, occurring without earthquakes. The signs of slow, or secular, movements can be seen most clearly along sea coasts.

In places where the crust is sinking, the sea gradually encroaches on the land, flooding coastal forests, fields, and buildings. For example, in the sixth century B. C. on the shore of the Bay of Taman, the large rich city of Phanagoria was founded, and today excavations reveal some of the streets of this city under water, since the sea here has noticeably encroached on the land. Modern subsidence is characteristic of the entire northern coast of the Black sea, the Kolkhida lowland, and the Kuban flood plain.

In the areas of slow crustal uplift the sea does not move in on the land but recedes. For example, the entire Scandinavian peninsula is rising. In Finland and Sweden, and on the coast of the gulf of Bothnia, the movement is so intensive that in the course of one generation it is possible to notice how shallow the narrows between islands are becoming, how groups of small islands are turning into one large island, how the shoreline is lowering, and how new sections of land are appearing.

Similar evidences of slow crustal movement were already noted by scholars of the ancient world, such as Aristotle, Strabo, and others. Systematic observation of slow movements was begun in 1731, in Sweden, when on the suggestion of Celsius special marks for registering changes in sea level were put on coastal cliffs. These marks, made originally at sea level, are now 1. 5 to 2 meters (m) above the water line (fig. 1). Knowing the height of the mark and

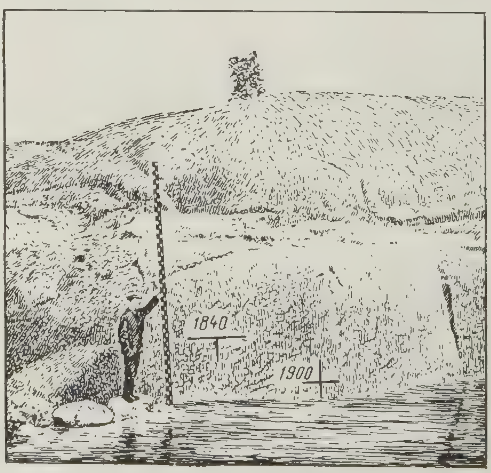


FIGURE 1. Marks on coastal cliffs in the region of the Fennoscandia contemporary uplift (after E. Kaäriainen). A mark made in 1840 at sea level is now about 1 m above the sea; a mark made in 1900 is 30 to 40 cm higher.

[1] Translated from Sovremennyye dvizheniya zemnoy kory: Priroda, 1958, no. 9, p. 15-24.

[2] Candidate in geographical sciences, Geographical Institute, Academy of Sciences, U.S.S.R.

the year it was made, it is not difficult to calculate the average yearly rate of rise of the crust. In the central part of the Scandinavian peninsula it reaches 1 centimeter (cm) per year.

Primitive marks are no longer adequate for observing changes in the position of the sea and land, and special level-measuring devices, depth gauges, and mareographs are used instead with highly precise results. For example, according to data provided by many years of level-measuring observations, the yearly rate of movement of the coastal land area at Tallinn [Ed.: Estonia S. S. R.] has been set at +2.3 mm, and at Odessa, -5.1 mm (the plus sign indicates uplift of the land, the minus sign, subsidence). Level-measuring observations are carried out regularly at many points on the globe. A summary of the results of such calculations was recently published by the International Geodetic and Geophysical Union [2 and 5], and the principal results are given on the maps.

Level-measuring observations describe movements of the earth's crust only along coastal belts. How can we determine the direction and intensity of movements of the crust in the interiors of land masses? Until recently science had proposed no reliable means to do this, and spaces inside all continents remained "white spots" on maps of modern tectonics.

Increased accuracy and volume of geodectic work has made possible the study of secular land movements by means of repeated leveling. For example, in 1921-1922, a precise leveling was made on a line from Moscow to Orel, and, in 1945-1946, the leveling was repeated. It was revealed that during the intervening 24 years the position of all high ponts (marks and datum points) had changed. In particular, in the Orel region the geodetic signs had risen approximately 80 mm. The accuracy of the leveling was so high that such a change is impossible to explain by errors of observation. Special investigations showed that this change could not be explained by purely surface causes, such as the settling or buckling of the ground at the base of the datum mark or the deformation of formations in which the marks were placed. Therefore, the changes in height must necessarily result from secular movement of the crust, and one must conclude that the Orel area is rising (in relation to Moscow) at a yearly rate of about 3 mm. By tying in the datum marks in the Orel and Moscow area (again using repeated levelings) with the depth gauges on the Baltic or Black seas, it is possible to calculate the rate of movement of the land in relation to sea level, that is, to obtain the absolute rate of crustal movement.

At present, many countries have accumulated a good many leveling lines, along which precise measurings of heights have been taken twice and even three times. These materials, and also the level-measuring data, have permitted the compilation of maps of contemporary movements of the crust for Finland, Japan, the United States and Canada, the Netherlands, England, Czechoslovakia, and other countries [3, 6, 7, and 8]. A particularly large area is covered in a map of contemporary tectonic movements of the western half of the European part of the U. S. S. R. [4], based on a network of repeated levelings of a general length of about 20,000 kilometers (km). The first leveling was carried out between 1913 and 1932, the second between 1945 and 1950. Repeated levelings were coordinated with depth gauges in Tallinn, Lepa, Odessa, Kerch, and at other points (processing of the level-measuring observations was directed by V. A. Zenin). As a result of the complex, labor-consuming calculations (in accordance with the method developed by M. I. Sinyagina), absolute velocity rates of crustal movement were determined (at millimeters per year) for 2,500 points. It is possible to set average yearly rates of uplift and subsidence for the eastern European plain at 2 to 4 mm; maximum yearly rates of movement (uplift) are as much as 8 to 10 mm. Uplift has been recorded for Tallinn (+2.3), Vilnius (+3.8), Baranovichi (+5.5), Sarny (+9.5), Kursk (+3.6), Kharkov (+3.9), the Krivoy Rog region (+10.8), and the Donets basin region (+3.7); subsidence for Vitebsk (-1.4), Moscow (-3.7), Leningrad (-3.6), Odessa (-5.1), and other points. Within the limits of the territory studied, several major zones of uplift can be noticed divided by zones of absolute and relative subsidence.

A very major zone of uplift, the Estono-Carpathian, extends from the coast of the Gulf of Finland to Moldavia, as if continuing the zone of modern elevation of Scandinavia. This fact is very interesting; until now it was supposed that the uplift fades out somewhere in Estonia and is not continued within the limits of the eastern European plain. The second zone of uplift, the central Russian, encompasses the uplands of that name and also the areas of the Donets ridge, the Azov massif, and the Krivoy Rog region.

Of the zones of subsidence, the one studied in most detail is the Ilmen-Dnieper zone of absolute and relative submergence extending from the gulf of Finland to the Black sea, and including the western part of the Moscow and Dnieper-Donets sedimentary basins. To the east of the central Russian uplift lies the Tambov-Kuban zone of subsidence. An independent area of subsidence corresponds to the borders of the Black sea-Azov depression. Also indicated is the Baltic zone of subsidence, encompassing western Lithuanian and the Kaliningrad region.

On the whole, contemporary deformations of the earth's crust in European U. S. S. R. represent major waves trending east. The transition from a zone of uplift to a zone of subsidence often occurs in a comparatively narrow linear belt having the appearance of a so-called flexure bend. The largest of these contemporary

flexures extend along the eastern borders of the Estono-Carpathian and central Russian uplifts.

How widespread are contemporary crustal movements? What laws govern the distribution of secular uplifts and subsidences? What is the nature of these movements? Unfortunately, we still have very few facts on which to base absolutely definite answers to many such questions. A variety of often contradictory hypotheses are given regarding the nature of contemporary movements and the laws governing them. Extensive material on contemporary movements in the eastern European plain allows us to throw new light on some of these problems; to evaluate critically the existing hypotheses; and, by comparing this with other territories, to attempt to note also certain general features and local peculiarities of contemporary movements.

ON THE DISTRIBUTION OF CONTEMPORARY MOVEMENTS ON THE EARTH'S SURFACE

Among geodesists and geologists exists the opinion that only certain mobile parts of the earth's crust are subject to contemporary movements and that other parts are stable. This view is being disproved by new data. It has been discovered that over the entire territory of the eastern European plain from the Baltic sea to the Black sea there is not a single area of any consequence in which secular movements are absent. Contemporary movements of one or another direction and intensity are revealed wherever it is undertaken to study them They cover mountain regions and plains, dry land, and sea bottoms. Thus the lithosphere, like the other covers of the earth, is in constant movement. It differs from the hydrosphere only in that each "wave" of uplift and subsidence of the crust develops over decades, and perhaps hundreds and thousands of years, and reaches immeasurably greater amplitudes than sea waves. It is just for this reason that, with depth-gauge observations, the level of the sea is used to register the movements of the earth; that is, over a long period of time the eternally undulating surface of the ocean is shown to be more stable than the surface of the hard earth.

The problem of intensity of contemporary movements and their place in the "spectrum" of oscillating movements of the earth's crust

Throughout the history of our planet, the earth's crust has experienced diverse complex movements. Uplifts and subsidences of the crust have brought forth transgressions and regressions of seas, the creation of mountains and depressions, and the formation of various geological structures of the crust.

Is it possible to equate contemporary movements revealed by repeated levelings with movements which formed the structure and relief of the earth, revealed by geological and geomorphological data? Let us turn to the analysis of the intensity of contemporary movements.

It has been established that slow crustal movements everywhere measure on the order of several millimeters a year. These rates of movement, which appear so small, are extremely high from the point of view of the geologist and geomorphologist. If we assume, for example, that the uplift of the Krivoy Rog area maintained its intensity (about 10 mm per year) for only the Quaternary (approximately 0.5-1 million years), there would now be mountains in this area over 5 km high. Obviously it is not possible to extend the rates of contemporary movements as revealed by repeated levelings over a long (geologically speaking) period of time. What is ths reason for this incongruity? Is it possible to hold that in the present epoch, in distinction from all preceding stages of geological history, the intensity of crustal movements has increased at an unusual rate? In our view, there is little justification for this assumption.

There is far more reason to suppose that crustal movements at any given moment of geological history have always had approximately the same intensity as now (on the order of 1 mm per year), but that the direction of movements at any point did not remain unchanged; that is, uplift was replaced by subsidence, which was then replaced by uplift. In the course of long periods of time there occurred what might be called a compensation of uplifts by subsidences, an averaging out of the results of movements (fig. 2).

Many geologists and geomorphologists believe that oscillations of the earth's crust are of complex character and can be broken down into ele-

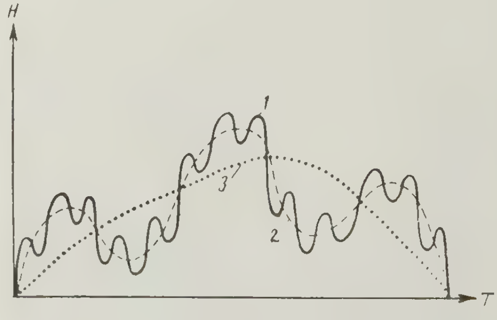


FIGURE 2. Diagram of oscillating movements of the earth's crust, tracing changes in height H of a point on the earth's surface during time T.
(1) movements determined by repeated levelings, (2) movements determined by geologic methods, (3) movements determined by geomorphic methods.

mentary oscillations of several orders. Oscillations of various amplitudes and periods are as if superimposed on each other. For example, the study of the geologic history of European U. S. S. R. allows us to distinguish first-order oscillation cycles lasting about 150 million years and having an amplitude to the order of several thousand meters, then cycles lasting about 30 to 40 million years, with a corresponding lesser amplitude and also a number of lesser rhythms (A. B. Ronov). As far as movements revealed by repeated levelings are concerned, in the complex "spectrum" of oscillations, they apparently correspond to oscillations of the highest order, with the shortest period, and a comparatively small amplitude. According to the descriptive observation of V. A. Magnitsky, the analysis of repeated levelings permits the discovery of what might be called the "microstructure" of oscillations, while geologic and geomorphologic methods give the possibility of judging their "macrostructure."

Geomorphologic investigations reveal that changes in the direction of movement have occurred in the quite recent geologic past. For example, geomorphologic analysis of postglacial forms of relief and depositions connected with them have shown that the contemporary subsidence established by repeated leveling in the area of Leningrad and Ilmen began no more than 3,000 to 5,000 years ago. Before this, the area went through a period of uplift, possibly an increased isostatic "emersion" of the crust after the melting of the glacier. However, there is no assurance that even during this very short period, geologically speaking, there were not a number of reversals of direction of movement in the Leningrad area.

It is clear that the question of the period and amplitude of modern oscillating movements is still unexplained. In principle it cannot be solved by geologic and geomorphologic methods, and the series of direct instrument observations of the course of crustal movement are still too short and too few. Some frequently repeated levelings in Japan give evidence of oscillating rhythms several decades long in all. On the other hand, it is known that the direction of movement of Fennoscandia (uplift) has not changed during two centuries of level-measuring observations (although the intensity of rise has changed periodically). It is possible that contemporary movements are of complex character, and that among them might also be distinguished oscillations of varying order--with periods of several decades and more. (Besides oscillating movements of tectonic origin, the surface of the lithosphere continually experiences oscillations of small amplitude caused by changes in atmospheric pressure, unequal heating of the earth's surface by the sun, and so forth. There are also oscillations of short period and small amplitude caused by the attraction of cosmic bodies, analogous to the tides of oceans and seas--the so-called "tides in rocks.")

The character of the appearance of tectonic movements is a question related to a number of the most controversial problems in contemporary geology. Certain scholars to this day reject in general the oscillating (direction-changing) character of movements; it isn't clear how oscillating movements are combined with the movements of individual structures. Direct observation of crustal movements demands frequent measuring over decades and even centuries. This task can be accomplished by the efforts of a number of generations of geodesists.

The significance of geodetic methods, particularly level measuring, for geology and geomorphology is well illustrated by the example of the Russian plain. At the end of the past century, conclusions A. A. Tillo drew from levelings provided the first correct ideas of its orography, and this gave the basis for important conclusions regarding the geological structure and history of this territory. At present it is possible not only to determine absolute heights of localities H, but also their change in the course of time, "first derivatives" ($\delta H/\delta T$). In the future it will be possible to discover changes in these changes, "second derivatives" ($\delta^2 H/\delta^2 T$), that is, to establish how crustal movements themselves change in time.

On the nature of contemporary movements

Contemporary movements disclosed by repeated leveling represent a special type of tectonic movement, differing fundamentally from those which form the geological structure and relief of the earth. With what factors and processes in the life of the earth's crust is the origin of contemporary movements related?

For a long time the nature of contemporary risings and sinkings of the lithosphere was explained by the hypothesis of glacial isostasy. According to this hypothesis, in regions of Quaternary glaciation (the Baltic and Canadian shields) the earth's crust must have been depressed under the weight of the ice masses. After the melting of the ice and the unloading of the crust, these regions emerged, whence is observed their rising. Nonglacial areas, according to this hypothesis, are either stable or sinking. However, even in nonglacial regions of the European U. S. S. R., a number of uplifts have been disclosed whose intensity (Krivoy Rog, 10 mm per year; the central Russian upland, 6 mm per year) is no less considerable than the uplifts in the center of glaciation in Fennoscandia. Outside the U. S. S. R., intensive uplifts are found in the islands of Japan, in the Indo-Gangetic plain, and in other regions which had also experienced no glacial cover. Thus, the hypothesis of glacial isostasy does not explain the distribution of contemporary uplifts and subsidences. This does not mean that the

glacial isostatic factor is not substantially reflected in crustal movement, particularly during the first period after the melting of the glacier. However, this factor sould be considered episodic and secondary.

In compiling maps of secular movements of the crust with the help of geologic and geomorphologic data, it seems that the direction of contemporary movements is largely determined by the structural heterogeneity of the territory. The crust is composed of various structural elements, among which tectonically uplifted and tectonically depressed sections (blocks) are of first order. Within the borders of the eastern European platform positive structures, uplifted blocks of the crust, are primarily rising (the Byelorussian-Lithuanian, Voronezh, and Ukrainian basement outcrops). These structural elements have had the tendency to rise for almost the entire length of geologic history. Many positive structures of the basement are expressed in relief by uplands (the central Russian upland, for example, is connected with the Voronezh basement outcrop), which testify to their rising not only in ancient geologic periods, but also in modern times. In contradistinction to the raised blocks of basement, the negative structures, tectonic depressions, are at present primarily sinking (the Dnieper-Donets and Black sea depressions). The relationship between the direction of contemporary movements and the peculiarities of the geologic structure is sometimes so complete as to be astonishing, if one considers that contemporary movements, in their intensity, cannot be identified with the movements which formed a given structure. For example, in the northern Russian plain the distribution of contemporary uplifts and subsidences repeats the ancient structural plan almost in entirety: the regions of the Moscow and Baltic syneclises are subsiding, while the structurally raised Byelorussian-Lithuanian zone dividing them is rising. Meanwhile the Moscow syneclise, as early as the Cretaceous period (over 70 million years ago), ceased to exist and was involved in an uplift. The reason for such a complete correspondence between contemporary movements and the ancient structural plan remains a mystery here.

Repeated levelings in other Russian-plain areas have shown that at present many extremely ancient structures are "alive," both major and minor ones. The intensive contemporary uplift of the Krivoy Rog area shows a clear connection with the ancient tectonic lines of the Ukrainian crystalline massif. In the northern Pre-Caucasus, a map of contemporary movements corresponds in places in detail to the structural breakdown of the territory (fig. 3).

The connection of contemporary movements with geologic structure and details of relief is being established as well for other territories, flat as well as mountainous. For example, in the Netherlands, which has been studied in detail,

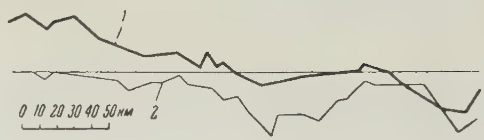


FIGURE 3. Profiles along a line from Rostov to Armavir.
(1) change in rate of contemporary movements according to data based on repeated leveling, (2) geologic structures based on data from geophysical investigations.

there is a great similarity between the map of contemporary movements (fig. 4a) and the structures of Tertiary deposits (fig. 4b). Sections where Teritary deposits are folded to great depth (to minus 1, 200 m in the Zuiderzee area) are experiencing the greatest subsidence; structurally raised sections are rising. In the islands of Japan, contemporary uplifts and subsidences correspond to the transverse anticlinal and synclinal zones indicated by the French geomorphologist Ruellan (plate I). The Scandinavian and Canadian uplifts are also tied in with major positive structures, shields which were steadily rising long before the ice age. However, in spite of significant interdependence there also exists considerable divergence between contemporary movements on the one hand and geologic structure and relief on the other. Thus, on the Russian platform individual raised blocks of the basement are subsiding at present, and structurally depressed blocks are rising (for example, the eastern and western parts of the Ukrainian crystalline massif are rising, and the central part is sinking). Within the borders of the Estono-Carpathian uplift, which corresponds to the structurally raised belt of the Russian platform, maximums of uplift are connected with relatively depressed sections, with the so-called Latvian saddle and Polesye trough.

The definite relationship between the distribution of contemporary uplifts and subsidences and the structural breakdown of the crust indicates, in our opinion, that contemporary movements as if by rule continue the trends of development operative throughout geologic history and impressed in the structure of the crust. Consequently, the source of contemporary movements lies in those processes which have formed geologic structure and relief. This is first of all the tectonic processes proper, which take place in the depths of the earth and are connected with the differentiation of material of the crust, with the displacement of magma, and with other, still to be studied, phenomena.

What is the connection between the idea of the oscillating rhythm of the movements, and the

FIGURE 4. Contemporary movements and the geologic structure of the Netherlands a - amplitudes of contemporary movements (in millimeters) for 1875-1877 to 1926-1940 (according to T. Edelman, 1954); b - depth of basal Tertiary deposits (in meters) (according to A. J. Pannekoeh, 1954).

facts pointing to the considerable inheritance of movements and to their connections with ancient structures? It is possible to assume that local peculiarities of oscillating rhythm reflect structural conditions of the area. Within the boundaries of raised blocks, the positive components of oscillating movements predominate and, within the boundaries of sunken blocks, the negative components predominate. For some blocks, the direction of movement is maintained for a long time, with the intensity of movement alone changing periodically (according to the sinusoid). In these cases, repeated levelings reveal contemporary uplifts of structural outcroppings and the sinking of structural depression, because with the oscillating character of movements various inconsistencies between contemporary movements and structure are inevitable.

An analysis of a map of contemporary movements creates the impression that, besides the movement of major blocks of the crust, contemporary movements also reflect tectonic phenomena of another kind, that is, major wavelike folds of the crust whose existence in the geologic past has already been remarked by A. P. Karpinsky. In European U. S. S. R., a meridional "wave" of uplift of very major proportions is formed by the Estono-Carpathian zone; parallel to it the Ilmen-Dnieper zone forms a wave of subsidence. The existence of contemporary meridional "waves" of the crust, superimposed on the mass movements of individual blocks, is confirmed by unfortunately extremely meager data on other territories. In particular, there are grounds for assuming a meridional "wave" in western Europe parallel to the Estono-Carpathian uplift and including the uplift of the British Isles, France, and the Iberian peninsula. The great role of meridional directions in the contemporary tectonic life of the earth is also revealed in seismic analysis: the majority of zones seismically active are grouped in meridional belts. And it is possible that it is not by chance that the contemporary uplift of Fennoscandia and the Estono-Carpathian zone lies on what might be a continuation of the active seismic zones of the Balkan peninsula and eastern Africa. Of course the above is not more than hypothesis. If we are able to speak with certainty of the tectonic (and not glacial isostatic) nature of contemporary movements, the grouping of various types of tectonic movements according to materials offered by repeated levelings remains a matter for the future.

The connection between contemporary movements and other processes in the interior and on the surface of the earth

Contemporary processes in the interior of the earth are manifested more clearly seismically. In particular, an earlier view of platforms as absolutely nonseismic regions is not valid. For example, during the past 150 years about 76 weak earthquakes have occurred on the Russian platform (S. S. Andreyev).

Rapid (seismic) and slow, oscillating crustal movements are apparently connected. However, this connection is complex, and its essence is far from clear. For example, these movements indicate a relation between epicenters of earthquakes and zones of large tectonic movements. The arrangement of earthquake epicenters in the

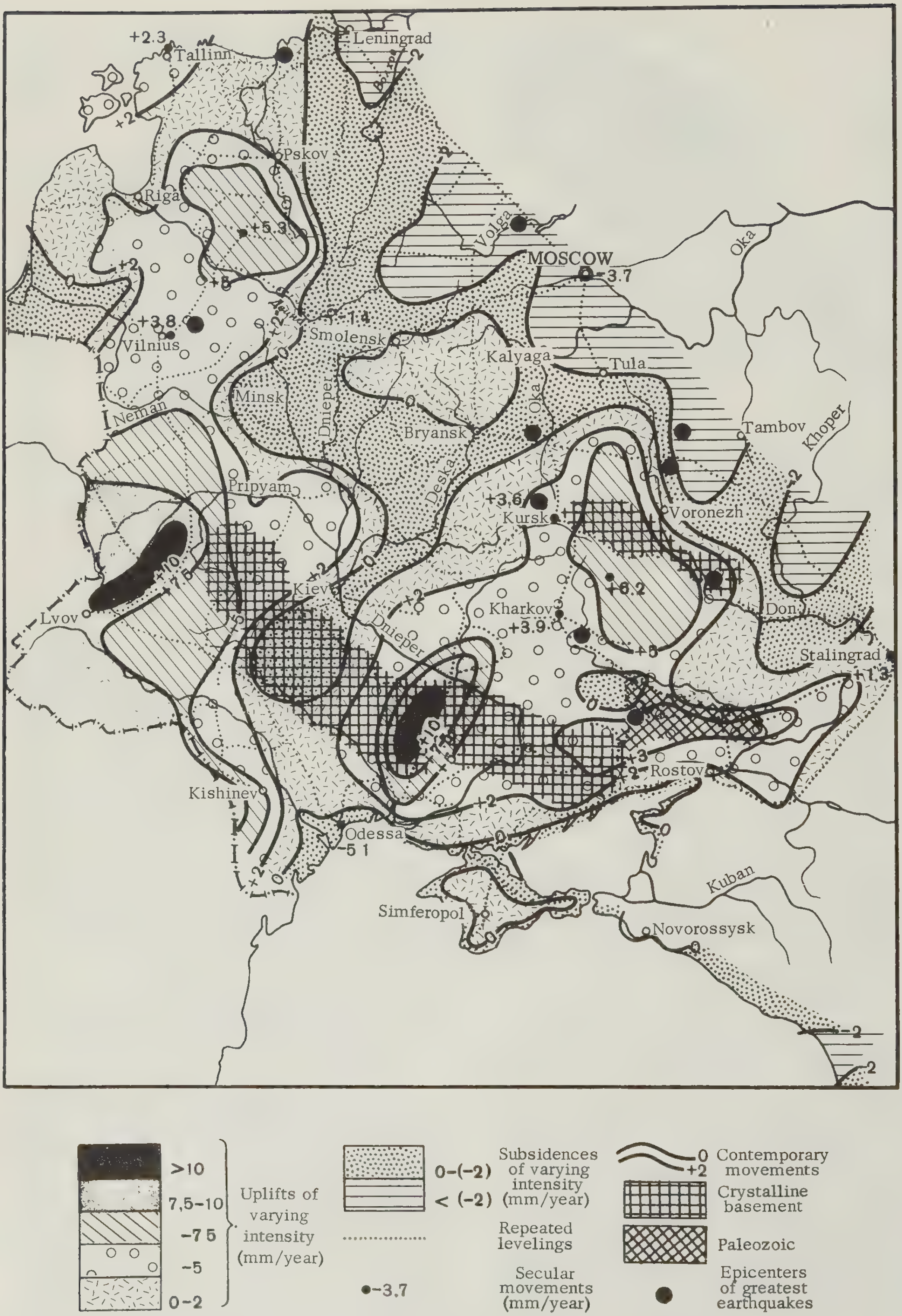


PLATE II. Schematic map of secular movements of the western half of European U.S.S.R. (Compiled by M. I. Sinyagina, A. V. Zhivago, V. A. Zenin, L. G. Kamanin, V. A. Mattskova, and Yu. A. Meshcheryakov; edited by I. P. Gerasimova, 1956)

Russian plain is actually related to the belt of greater contemporary movements along the "slopes" of the central Russian uplift and the northern part of the Estono-Carpathian zone. However, sections of still greater movements in the south of the Russian platform for the same period, were not seismically active. In the islands of Japan there is also no complete general correlation between the gradients of movements and the distribution of epicenters.

If we are to compare as a whole seismic activity and contemporary movements in the orogenic Japanese islands and on the Russian platform, then an even greater discrepancy appears: these two territories do not differ so strongly in intensity of contemporary oscillating movements as might be expected from the seismic acitvity occurring in them. In general, apparently, short-period oscillations of the crust, revealed by repeated leveling, do not differ much in intensity in platform and orogenic regions. The reasons for this are still far from clear.

Until recent times the absence of reliable quantitative data did not permit consideration of the influence of contemporary movements on the processes of formation of relief and continental sediment accumulation. Clearly this is why it was thought that such an influence is insignificant particularly in the "quiet" platform regions. Nevertheless, many facts testify to the great influence of contemporary movements on various processes taking place on the surface of the earth. It is true that this influence is hidden by the conditions of the relief, by peculiarities of climate, soil and ground cover, and others. Nevertheless, the role of the tectonic factor is often expressed quite clearly. For example, it has been shown that in the Baltic area the distribution and size of peat bogs are determined to a significant degree by secular movements. The largest peat deposits are connected with areas of subsidence. Thus, in southern Estonia, where there is comparative submergence, the thickness of peat deposits may be as much as 6 to 7 m. The accumulation of peat is stimulated here by the gradual rise of the level of ground waters while the land is subsiding. In northwest Estonia, where uplift is taking place, the contrary is observed: the ground-water level is gradually lowering; peat formation proceeds at a reduced rate. The thickness of peat deposits here is not more than 1 m.

In the south Russian steppes, contemporary movements influence gully erosion. Areas of recent uplift, all other conditions being equal, are distinguished by many gullies and the increased rate of their growth.

The influence of secular movements on the work of rivers is exceptionally great. Every river current tries to form a so-called "profile of equilibrium," with a gradual uniform lessening of the longitudinal slopes downstream. If a growing uplift or subsidence is met on the stream's path, the normal work of the river is disturbed. In section of uplift, where tectonic forces tend to raise the river bed somewhat, the river, in order to preserve its profile of equilibrium, deepens its bed intensively. In addition, rapids are often formed in the channel, and sometimes genuine waterfalls. The river valley is such areas is narrow and canyonlike. The amount of river (alluvial) deposits is usually small. Examples might be the valleys of the central course of the Zapadnaya Dvina, the Neman, and the rivers of northwestern Estonia, which correspond to regions of intesive crustal uplift (fig. 5).

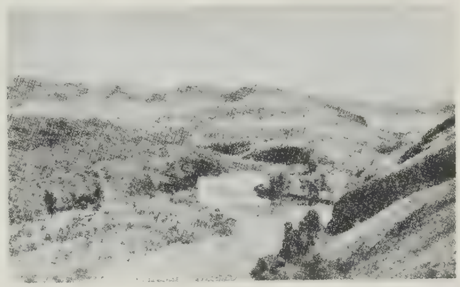
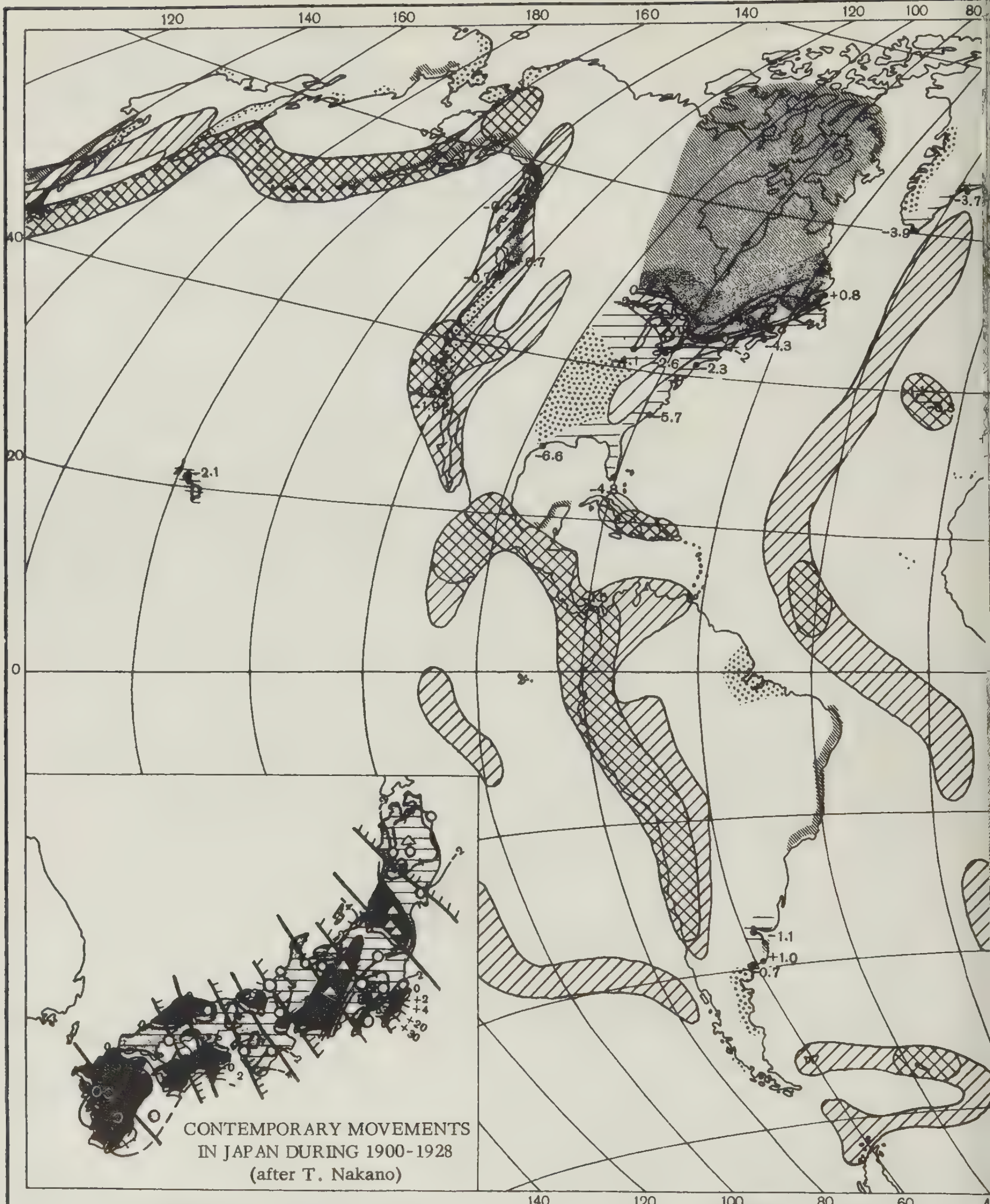


FIGURE 5. Typical view of a river valley in a region of intensive crustal uplift

In areas of subsidence, where secular movements tend to lower the level of the longitudinal profile, the river does not cut its way it, but fills its bottom with sediment. Therefore, in areas of subsidence alluvial deposits are greater; river valleys are broad, sometimes swampy and the current is slow and tranquil. Examples are the flood plain of the Kuban, the central course of the Dnieper, and the rivers of the Tambov lowland (fig. 6). On a considerable part of the territory where secular movements were studied, special geomorphologic investigations were carried out to determine the direction of river action. A comparison of the results of these investigations with a map of secular movements has shown that very many of the characteristics of river valleys can be explained by the direction of contemporary tectonic movements.

FIGURE 6. Typical view of a river valley in a region of crustal subsidence



SUPPLEMENTARY SYMBOLS
(for insert)

Axes of modern transverse uplifts

Axes of modern transverse troughs (after Ruellan)

Contemporary volcanism

Epicenters of earthquakes

SLOW SECULAR MOVEMENTS

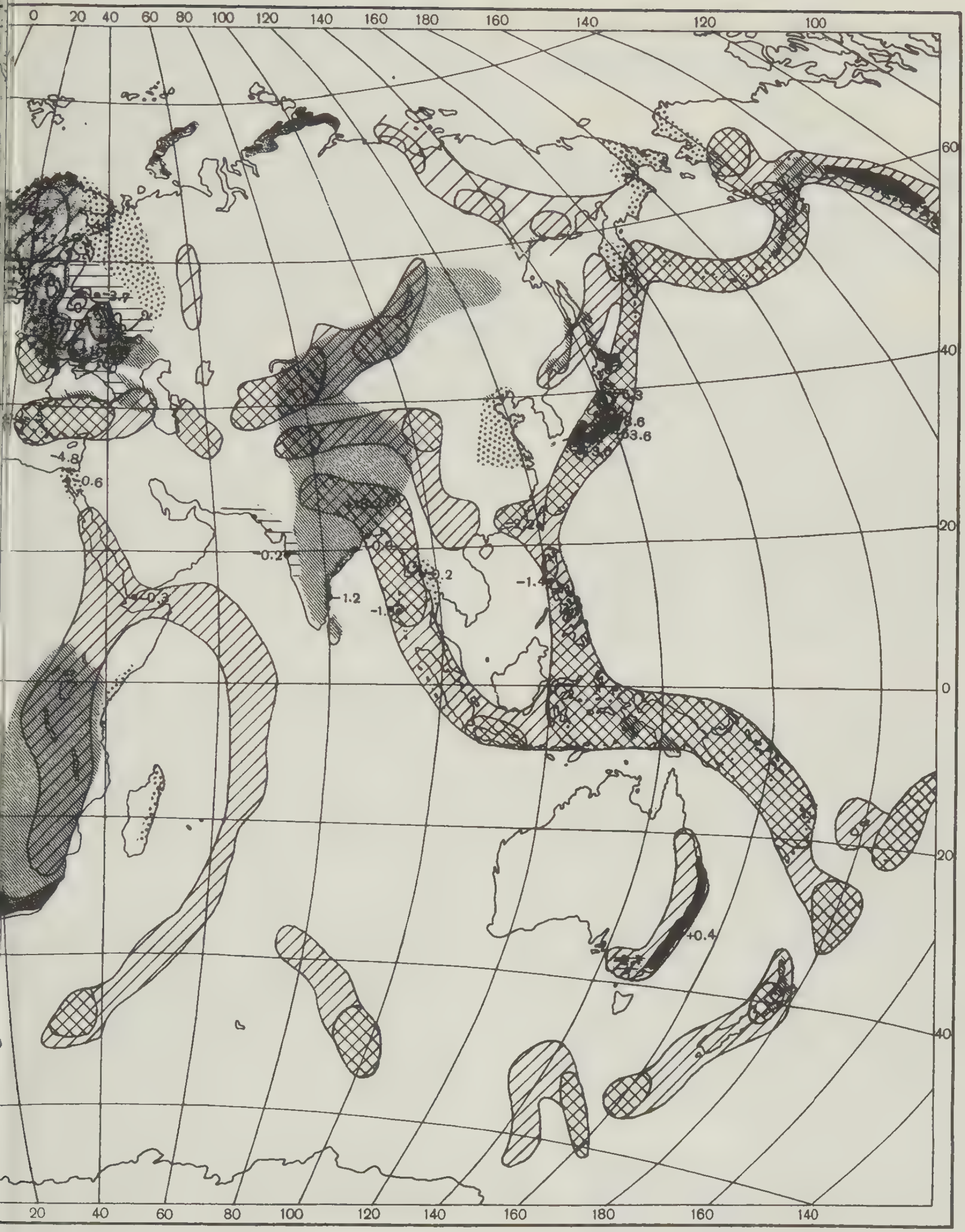
Regions of contemporary uplift, known and inferred

Regions of contemporary s sidence, known and inferr

0 +2 Isoclines of secular move

• -3.7 Rate of secular movement (mm per year)

PLATE I. Schematic map of contempo



RAPID (SEISMIC) MOVEMENTS

Regions of intensive and frequent earthquakes

Regions of milder and less frequent earthquakes

Individual zones of rare and weak earthquakes

. movements of the earth

This has served as convincing testimony to the correctness of maps of secular movements compiled according to data from repeated levelings.

CONCLUSIONS

"The present is a result of the past and an indication of the future," wrote V. G. Belinsky. Contemporary movements, being closely tied to the territory, permit us to judge the future trends of its development and give a prognosis of crustal movement.

Although contemporary movements are measured in a few millimeters per year, they nevertheless influence certain aspects of human activity. Well known, for example, is the case in which local uplifts and subsidences of the crust deformed the water main in one of the major cities of the Caucasus. We remember that because of secular subsidence, Hollanders are obliged to protect their country from inundation by building a complex system of dams. With increased precision and number of engineering projects, the consideration of secular movements becomes a necessary element in long-term planning of complex construction such as ports; hydroelectric stations; canals; irrigation systems; and oil, gas, and water pipelines.

Data on contemporary movements are very important in analyzing seismic activity. For example, Japanese researchers consider observations of slow crustal movements the most effective means of solving the problem of predicting earthquakes [1]. In Japan, over 25 stations carry on regular observations of secular movements; a connection has been disclosed between earthquakes and sharp reverse crustal movements, breaking the monotonous secular process. For example, the catastrophic earthquake in 1923 in the area of the gulf of Sagami was predicted by a sharp uplift of the gulf shoreline, which had been sinking over a long period of time before this. Although criteria for a prognosis of earthquakes can still not be considered finally established, the study of slow movements even now gives the possibility of predicting the seismically most dangerous areas.

Materials on contemporary movements obtained by geodetic methods have considerable meaning for geodesists themselves. With the present demands for accuracy of geodetic data, the consideration of crustal movements becomes necessary in planning supporting geodetic networks and maintaining them at a high level of accuracy.

Data on secular movements is extremely significant for the solution of a number of problems in geology, geophysics, and physical geography. Because the distribution of many minerals is determined by tectonics, the study of crustal movements is of practical use, particularly in interpreting the tectonics of oil-producing areas and the search for new oil traps.

The study of contemporary crustal movements is now being carried out in many counties. This problem occupies a definite place in the activities of the International Geodetic and Geophysical Union (IGGU), in which over 50 countries are represented. Soviet researchers, highly praised at the recent XIth Assembly of the IGGU in Toronto (Canada), besides being distinguished for the great extent of the territory they represent, are distinguished by their sustained complex approach, that is, the organic combination of geodetic, oceanographic, and geologic methods. This approach assures not only the achievement of the desired results, based on the consideration of many aspects, by also opens to the researcher the broadest and most fascinating perspectives; it is an approach which allows still deeper penetration into the chain of interconnection in nature, and the discovery of new laws having practical as well as theoretical significance.

REFERENCES

1. Beloussov, V. V., In: Mezhdunarodnyy Geofizichesky God [International Geophysical Year]: 1957, no. 3.
2. Committe, Assoc. Phys. Oceanography, SECULAR VARIATION OF SEA LEVEL: Geod. & Geophys. Union, Internat. Publ. Sci., 1954, no. 13.
3. Gerasimov, A. P., MEDLENNYYE DVIZHENIYA SUSHI I IKH IZUCHENIYE [SLOW, DRY MOVEMENTS AND THEIR STUDY]: Priroda, 1927, nos. 7-8, p. 551-556.
4. Gerasimov, I. P., and Yu. V. Filippov, SOVREMENNYYE VERTIKALNYYE DVIZHENIYA ZEMNOY KORY NA TERRITORII ZAPADNOY POLOVINY EVROPESKOY CHASTI SSSR [CONTEMPORARY VERTICAL MOVEMENTS OF THE EARTH'S CRUST IN NORTHWESTERN EUROPE TO U. S. S. R.]: Akademiya Nauk SSSR, Trudy, v. 123, 1958.
5. Gutenberg, B., CHANGES IN SEA LEVEL, POSTGLACIAL UPLIFT AND MOBILITY OF THE EARTH'S INTERIOR: Geol. Soc. America, Bull., v. 52, no. 5, 1941.
6. Karlov, N. N., SOVREMENNYYE TEKTONICHESKIYE DVIZHENIYA V CHEKHOSLOVAKII [CONTEMPORARY TECTONIC MOVEMENTS IN CZECHOSLOVAKIA]: Priroda, 1957, no. 10, p. 92.
7. Meshcheryakov, Yu. A., SOVREMENNYYE TEKTONICHESKIYE DVIZHENIYA BALTYSKOGO I KANADSKOGO SHCHITOV [CONTEMPORARY TECTONIC MOVEMENTS OF THE BALTIC AND CANADIAN SHIELDS]: Priroda, 1950, no. 2, p. 24-25.

8. Meshcheryakov, Yu. A., SOVREMENNYYE TEKTONICHESKIYE DVIZHENIYA BRITANSKIKH OSTROVOV [CONTEMPORARY TECTONIC MOVEMENTS IN THE BRITISH ISLES]: Priroda, 1955, no. 2, p. 89-92.

AN ATTEMPT AT STUDY OF INCLUSIONS IN MINERALS OF MURZINKA (URAL) PEGMATITES[1]

by .

V. V. Yakubova

• *translated by V. P. Sokoloff* •

ABSTRACT

Direct determination of temperatures of development of pegmatites of Murzinka, in the Urals, by homogenization of inclusions in minerals is scarcely possible. In places where nourishment of the crystal is impaired, not only one, but several, inclusions develop, regardless of the mechanisms responsible for impairment. Such groups of inclusions may represent single systems in disequilibrium or several generations of heterochronic inclusions. The degree of equilibrium depends on the degree of solubility of the mineral substance in the medium captured. Phase ratios may be disturbed in the course of reorganization within primary inclusions. --G. E. Denegar.

INTRODUCTION

Quartz is the only mineral separating throughout the entire course of the mineral-formation at the site affording thereby ample means for a single-value solution of the sequence problem in the crystallization of its varieties. In the initial stage of the mineral-forming process, quartz is separated as a regular growth simultaneous with feldspar forming the graphic-structured pegmatites. Further separations, in the pegmatoid stage, with the large growths of feldspar and mica, are in the form of rather remarkable crystals of smoky quartz, with an occasional regular overgrowth of grayish-violet quartz, which may show a genuine amethyst coloration.

A. Ye. Fersman [15] had established the following sequence for the separations of quartz, based on his studies of a large number of samples: a) pale-smoky quartz at 800° to 600° C, b) dark-smoky quartz at 600° to 575° C, and c) an interruption in the deposition of quartz at 575° to 475° C (Corrosion, mechanical fragmentation, and coating of quartz with albite take place within this range.). Crystallization of gray quartz is resumed at 475°C, with ash-colored quartz superseding at 450° C. Colorless quartz follows at 400° to 250°C and the entire process is terminated at 250° to 100° C by the separation of amethyst.

Existence of the series of quartz varieties, commonly showing zonal structures, and the possibility of establishing the sequence of their separation incontrovertibly make quartz a rewarding object of study in the verification of temperature, calculated for the mineral-forming environment from the homogenization temperatures of the gaseous-liquid inclusions.

QUARTZ OF GRAPHIC-STRUCTURED PEGMATITES

According to Fersman [15], the highest temperature quartz is quartz in the graphic-structured pegmatites. In Fersman's view, the simultaneous growth of quartz and feldspar takes place at 700° to 600° C, with a concurrent development of pegmatitic structures. For this reason, high-temperature alpha-quartz grades into beta-quartz, the low-temperature variety, with the accompanying significant diminution of its volume. Fersman cites the data of Sosmann for the volume changes in quartz and feldspar.

The volume changes in quartz may amount to 4. 5-5 percent, on cooling from 600° to 300° C, while, in feldspar, they may be only 0. 5 percent. Consequently, on cooling of the graphic-structured pegmatites, the compression of quartz will be different from that of feldspar, with the consequent and inevitable disruption in the continuity of the structures.

With cracking within the grains of quartz due to nonuniform contraction, interspaces between quartz and feldspar--subject to subsequent healing--should develop. Moreover, small cracks developing from contraction of quartz could cause a fragmentation of feldspar, at least of its granules enclosed in quartz, with a development of cracks common to both feldspar and quartz.

On the examination of 37 thin sections cut perpendicular to the direction of growth of the graphic pegmatite, it was found that the kernels of quartz in the ichthyoglypts contain numerous inclusions whose planes end abruptly at the quartz-feldspar interface. No healed cracks could be detected either in the feldspar itself or at the boundary between the feldspar and the quartz-bearing ichthyoglypts [Ed. : Term not defined in standard dictionaries; meaning to be inferred from text]. The quartz-feldspar boundary in graphic pegmatites is distinct and regularly outlined.

In our studies of the ichthyoglypt inclusions,

---

[1]Translated from Opyt izucheniya vklyuchenny v mineralakh pegmatitov Murzinki (Ural): Akademiya Nauk SSSR, Trudy Mineralogicheskogo Muzeya, v. 7, p. 132-150, 1955.

we were not able to establish any regularity in their distribution. Positions of the inclusions in reference to crystallographic axes, and their association with growth zones serve as criteria of their primary or secondary origin. Such relationships may be seen clearly only on examination of the whole crystal. In dealing with thin sections, however, even with oriented ones, the problem of primary or secondary origin of the inclusion simply could not be solved in a number of instances. Just the same, secondary inclusions are fully as interesting as the primary ones in a comprehensive study of the pegmatite, because they too may be characteristic of a certain stage in mineral formation.

Two kinds of gaseous-liquid inclusions were observed in the ichthyoglypts: 1) two-phase inclusions consisting of a solution and a gaseous bubble (29 samples), 2) three-phase inclusions consisting of two liquid phases -- solution and liquid carbonic acid -- and a gaseous bubble (8 samples). No solid phase could be detected in any of the thin sections, although the solid phase is present in some inclusions in some other minerals.

Most of the inclusions in the ichthyoglypts are very small. It was not possible, therefore, to observe their responses to heating or to determine the temperature of their homogenization. In cases where the inclusions were sufficiently large to make their study feasible, they were heated in the N. P. Yermakov microthermochamber until homogenization was complete. Consequently, highly inconclusive data were obtained (table 1).

TABLE 1. Homogenization temperatures for ichthyoglypt two-phase inclusions

Sample number	Homogenization temperature (C)
4F	225^{o} and 190^{o}
20353	280^{o} and 300^{o}
14F	240^{o}
43F	180^{o} and 100^{o}
70F	230^{o} and 180^{o}
78F	200^{o} and 100^{o}
69F	220^{o}
79F	225^{o} and 220^{o}
20362	225^{o} and 125^{o}

Temperatures obtained for ichtyoglypts containing the three-phase inclusions are presented in table 2.

TABLE 2. Homogenization temperatures for ichthyoglypt three-phase inclusions

Sample number	Homogenization temperature (C)
47F	200^{o} and 225^{o}
47F*	135^{o}
68F	250^{o} and 225^{o}
68F*	180^{o}
71F	250^{o}
72F	200^{o}

* Liquid CO_2 absent.

The inconsistent data obtained for inclusions in the same system make it impossible to establish the temperature of their formation. A comparison between the homogenization temperatures of inclusions in different samples is likewise impossible. Also, we did not succeed in establishing any regularity in the distribution of the inclusions in our studies of the thin sections, nor a regularity that could suggest that quartz of the ichthyoglypts is the high-temperature modification and, consequently, a paramorph of beta-quartz on alpha-quartz.

An unusually peculiar phenomenon generally draws our attention in studies of pegmatites; namely, the elutriation of the ichthyoglyptic quartz from the graphic-structured pegmatites. It appears unexplainable by what agent would it be possible for the quartz to become so completely elutriated, while the feldspar could remain fully intact. If the elutriation of quartz was complete, the remaining feldspar, penetrated throughout by a network of cavities, resembles a sponge. In these cavities, one may discover crystals of transparent albite, fine crystals of transparent topaz (type IV, in Fersman's classification), and mica. A peculiar example of such elutriation of ichthyoglyptic quartz was observed in sample 69F.

This specimen is a crystal of orthoclase with an ingrowth of ichthyoglypts. The ichthyoglypts do not reach the surface of some faces of the crystal. Their crystallization ended before crystallization of the orthoclase. At the 001 face of the orthoclase, the ichthyoglypts are terminated by small crystals of smoky quartz covered by a buff crust.

One of these crystals appears to have grown inside a vacuole, in the feldspar. The vacuole, in its cross-section plane, has an outline of an irregular hexagon, with its sides parallel to the crystal faces of the quartz it contains. Some of the neighboring quartz crystals likewise do not have direct contacts between their crystal faces and the orthoclase and, in all probability, appear to have grown within the vacuoles in the orthoclase. One crystal face contains a vacuole containing quartz that had failed to crystallize. If we examine the internal structure of this crystal, on fracturing, we may see that the ichthyoglyptic quartz has been elutriated partially from the ichthyoglypts in the orthoclase, whereupon cavities bordered by the induction faces developed. A two-pointed crystal of smoky quartz was crystallized on one of the walls of this cavity. This crystal lies on the wall of the prism, at an angle to the long axis of the former ichthyoglypt. It is evident that this crystal, even as the quartz crystal at the 001 face of the orthoclase, was formed after the partial elutriation of the quartz from the ichthyoglypts.

A thin section passing through the center of a quartz crystal with the parallel orientation

with respect to its vertical axis was made. It was discovered in the thin section that a peculiar phantom of quartz or, more exactly, a part of it caught luckily by the section, is plainly visible in the part of the ichthyoglypt farthest away from the surface of the orthoclase (fig. 1). One may see the crystalline boundaries of this phantom.

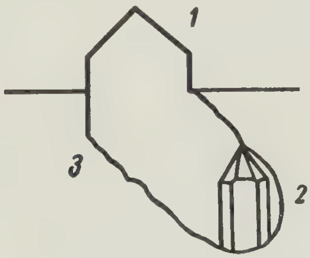


FIGURE 1. A phantom in an ichthyoglypt (quartz, sample 69 F)
(1) head of ichthyoglypt, (2) phantom, (3) ichthyoglypt.

The orientation of the phantom corresponds fully with the orientation of the crystal constituting the head of the ichthyoglypt. The vertical axis of the phantom makes an angle of approximately 47^{o} with the longer axis of the ichthyoglypt. The development of such peculiar phantom within the ichthyoglyptic quartz shows that the quartz was growing freely and without any inductive influence from the feldspar.

Striations on the walls of cavities containing large inclusions found in the same ichthyoglypt are parallel to the joint between the prism and the rhombohedron forming the head of the ichthyoglypt — an indirect indication in support of the foregoing view. It was established that the striations may be observed on the walls of the cavities containing large primary inclusions. These striations are commonly oriented in the same manner as striations on the faces of the prism of the host crystal. This may be taken as the basis for the conclusion that the growth of quartz within the rest of the ichthyoglypt was taking place not in the direction of the ichthyoglypt's longer axis but in the direction coinciding with the vertical axis of the terminal crystal of the ichthyoglypt.

If we consider these facts in reference to the presence of cavities both within the crystal of orthoclase and at its faces surrounding the terminal crystals of the ichthyoglypts, it shall become evident that the ichthyoglyptic quartz is secondary in the orthoclase, that it had crystallized in the cavities formed after elutriation of the primary quartz, and the striations at the boundary of the ichthyoglypt are pseudoinductional, conditioned by the form of the cavity--and replicated by the secondary quartz. This constitutes a premise for a supposition that the elutriation of ichthyoglyptic quartz from the graphic pegmatite was taking place on a scale larger than it appears on the basis of the study of our samples. Possibly, a secondary redeposition of quartz in the ichthyoglypts may account for lack of its consistent coloration, contrary to the teaching of Fersman. Dark-smoky quartz having the same hue as quartz of the pegmatoid phase may occur with light-smoky quartz.

Causes of the elutriation of ichthyoglyptic quartz may be understood, more or less, if we refer to the more recent works on solubility of quartz and to some experimental results with the artificial growth of quartz [4, 16, 17]. G. C. Kennedy shows that solubility of quartz in water is strongly influenced by the pressure. This influence is especially pronounced at the hypercritical temperatures and pressures. Pressure in hypercritical environments is the factor that determines the specific density of the medium directly. The specific density has a decisive influence on the solubility of quartz in water under hypercritical conditions. The fact is characteristic that, at pressures below 750 bars and at hypercritical temperatures, the solubility of quartz in water is diminished with an increase in the temperature.

It is within this particular interval of pressure, from the critical to 750 bars, that the specific volume of water is at its maximum and, consequently, its density is at the minimum. As the pressure is increased above 750 bars, the solubility of quartz also increases significantly, while increasing temperatures also cause increasing solubilities.

These results were utilized by N. N. Sheftal [17] in explaining solubility phenomena in quartz crystals growing artificially in an autoclave and extended also to account for the phenomena of solubility and redeposition of quartz in the crystal cellars of quartz-bearing rock.

Inclusions in minerals of the Murzinka pegmatites were mainly aqueous, indicating that the pegmatitic melt was water saturated. Upon crystallization of the graphic pegmatite, water evidently became the principal component of the fluid and, later, of the hydrothermal solution by which cavities in the pegmatitic body were filled. Therefore, Kennedy's data [4] on solubility of quartz may be utilized somehow in explaining the elutriation of quartz during the crystallization of the deposit.

Pegmatites, according to Fersman [15], develop at considerable depths (4 to 8 kilometers) and, consequently, under lithostatic pressure of about 1,000 to 2,000 bars. It follows that density of the pegmatite-forming medium must be appreciable, despite its hypercritical temperature. This is confirmed, for the Murzinka pegmatites, by the phase ratio within the inclusions in the minerals. The liquid phase is

preponderant commonly over the gaseous phase which is possible only if the captured substance had an appreciable density. The reverse phase relationship was found only in anomalous cases where an excess of gaseous phase was acquired by the inclusions in the course of their evolution during the rearrangements in the cavities.

The graphic pegmatite at Murzinka crystallized in a closed system at temperatures above $600^{o}C$ and at pressures of approximately 1,000 to 2,000 bars. On lowering of the temperature but with pressure maintained above 750 bars and in the absence of further accessions from the magmatic furnace, the normal effect is the deposition and not the dissolution of quartz. It is evident that the cause of increased solubility of quartz in the same mineral-forming environment and the falling temperature could be only the increase in the specific density of the medium. Such increase could be the result only of increased pressure under conditions of crystallization in a closed system.

One may suppose that a compression of the mineral-forming medium may have taken place, under lateral pressures, after the termination of the crystallization of the graphic pegmatite, and, consequently, an increase in the solubility of quartz in the medium. The ichthyoglyptic quartz was partially elutriated. In the course of time, locally, cavities in the feldspar could have become refilled by quartz, while in some other places they were preserved and were filled by some other minerals.

Fersman [15] believes that dissolution and elutriation of quartz, as well as the tectonic phenomena, took place at the boundary between the pegmatoid and the hypercritical phases. The secondary deposition of quartz discovered by us in the ichthyoglyptic cavities, terminated by a crystal growth of quartz and a development of the head of the pseudoichthyoglypt, indicates that this process (the secondary deposition) was taking place earlier, namely, directly after the crystallization of the graphic pegmatite to the pegmatoid phase.

Thin section prepared from quartz, sample 69F, contains inclusions having the same phases: a solution and a gaseous bubble, although the phase ratio is not the same in different inclusions.

In some cases, it is distinctly seen that, even in the case of inclusions belong obviously to the same system, the phase ratio is not the same. The difference in the phase ratio can mean only a difference in the homogenization temperature of the inclusions and also a difference in the direction of the process. Figure 2 shows a group of inclusions in quartz (sample 69F). All of these belong to one system. There can be no question as to a possible superimposition of two heterochronic systems. Microscopic studies bring this out distinctly. The two upper inclusions, adjacent to each other, have a highly different phase ratio. The left inclusion contains a small gaseous bubble and homogenizes at a low temperature. The right inclusion must be gas filled. The large inclusion, in the lower part of the photograph, has the phase ratio still different from the former two. It should homogenize at some temperature, peculiar to itself, and should become filled by the liquid, like the first one, on its homogenization.

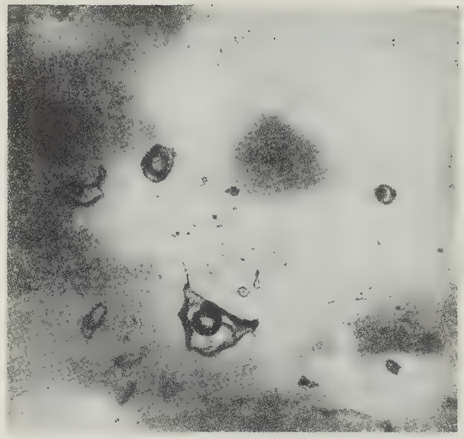


FIGURE 2. A group of inclusions simultaneously formed but having a different phase ratio (quartz, sample 69F, x 150)

We did not heat this specimen, but we wished to preserve it intact. It was evident, however, that three different temperatures would have been obtained were the inclusions here described subjected to homogenization. Moreover, according to N. P. Yermakov [1], we ought to conclude that one of the inclusions (the first one) had captured the mineral-forming medium in its gaseous state and the other two, a medium which was a hydrothermal solution. Absurdity of such a conclusion is self-evident. How is it then that we could account for the existence of simultaneously formed inclusions having different phase ratios? This may be explained easily by reference to the experiments of G. G. Lemmleyn and M. O. Kliya [5-12].

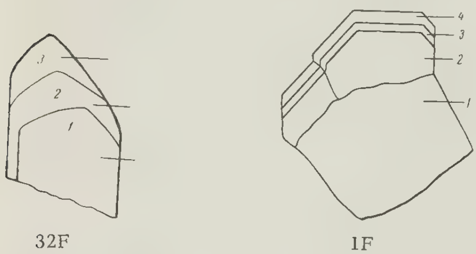
Single inclusions are rarely found in minerals. Commonly, regardless of whether they are of the primary or the secondary origin, a group of inclusions form simultaneously, often interconnected, and constituting a system in disequilibrium. In a manner analogous to the inclusions in the experiments of Lemmleyn and Kliya, such system will tend to attain its equilibrium. Individual inclusions will separate themselves from the adjoining ones and will rebuild the forms of their cavities. These processes will continue as long as the mineral substance continues to be soluble in the solution enclosed within the cavity of the inclusion. Inclusions with anomalous phase ratios may be developed concurrently, very much like in the case of the

secondary inclusions in Lemmleyn's and Kliya's experiments. The inclusions in sample 69F evidently represent such a case. From this point of view, we may account for the differences in the homogenization temperatures for inclusions belonging to the same system in the ichthyoglyptic quartz. This phenomenon is presently to be discussed in detail.

FIGURE 3. Solid phase (borax) within an inclusion (quartz, sample 1F, x 210)

QUARTZ OF THE PEGMATOID STAGE OF MINERAL-FORMATION

Quartz of the pegmatoid stage of Fersman's classification [15] is a rewarding material in the sequence definitions of the separations of its varieties. Large crystals of smoky quartz with zonal colorations (fig. 4) are common at



32F 1F

FIGURE 4. Zonal structure of quartz
Sample 32 F: (1) milky, (2) smoky, (3) colorless;
Sample 1 F: (1) milky, (2) pale smoky, (3) dark smoky, (4) colorless

Murzinka. The color of the quartz is a typomorphic indication because the ichthyoglypts of the graphic-structured pegmatites show no uniform coloration and their color is not typomorphic. The central part of the crystals is composed of a gray milky quartz grading into a more transparent smoky quartz. The absence of any distinct boundary between the two is indicative of a continuous crystallization. The smoky quartz commonly is not uniformly colored. Its coloration is zonal, tending generally to increase in its intensity [Tr.: toward the periphery].

The darker and the lighter bands alternate locally. The colorless quartz grows on top of the smoky quartz. There was an interval between depositions of these two kinds of quartz, as is shown by the sharp distinctive boundary between the two. In some samples, the envelope composed of the colorless quartz may be removed without any injury to the faces of the smoky quartz. Within the colorless quartz, there may be inclusions of the finest plates of mica and of tourmaline crystals separated apparently before deposition of the colorless quartz. Since none of the smoky quartz crystals are translucent, their detailed examination required preparation of thin sections through the center of the crystal with the orientation parallel to its vertical axis. The central part of sample IF (fig. 4) is grayish-milky quartz; then follows the smoky-quartz zone, with an increasing color intensity at its boundary with the colorless quartz; a narrow band of colorless quartz is situated on top. The greatest number of inclusions is found in the grayish-milky quartz; hence its coloration.

Distribution of the inclusions in the thin section cut through the center of the quartz crystal, parallel to the vertical axis, resembles very much the perthite structure of feldspars. The perthite structure is characterized by a regular and parallel distribution of perthite ingrowths, although individual ingrowths may have indefinite and vague outlines. This is also characteristic for the distribution of the inclusions in milky quartz.

The inclusions in milky quartz are found in separate groups elongated perpendicularly to the vertical axis of the quartz crystal and generally having irregular and diffuse outlines. There is a definite regularity in the distribution of the groups with respect to each other; they are strictly mutually parallel.

A considerable resemblance is noted between the structures of our section and of the skeletal quartz. The faces of the skeletal crystals also showed parallel accretions and alternations of the cavities. Evidently, groups of inclusions are formed in different areas of the growing crystal because of irregularities in the inflow of the nutritive liquor. These groups constitute one single system in disequilibrium which, even as in the case of the secondary inclusions, does not remain stable through the lifespan of the pegmatite, but is subjected to a number of changes, while it tends to assume the most stable condition of equilibrium with surface energy at minimum. We arrived at this interpretation of the inclusions toward the end of our research when results of the brilliant experiments of Lemmleyn and Kliya became known. At the beginning of our work, however, following the recommendations of Yermakov [1], we attempted determinations of the temperature of the formation and, consequently, the temperature of the separation sequence for different zones of quartz by the means of homogenization

of the more regularly outlined individual inclusions. This attempt was doomed to failure from its very beginning because it was methodologically incorrect.

A thin section of quartz was split into a number of finer sections. From these, the better suited and the larger inclusion-bearing parts were selected for our investigations after a study under the microscope. They were heated in Yermakov microthermochamber until the inclusions were homogenized. The majority of the inclusions contained two phases and some of them had also a solid phase in the form of pseudohexagonal plates and crystals (figs. 3 and 5). These were identified as borax by their solubility and form, as well as by their analogy the same kind of inclusions in quartz collected at the same site that were analyzed previously, both microchemically and spectrographically [18]. Inclusions containing carbonic acid were very rarely observed.

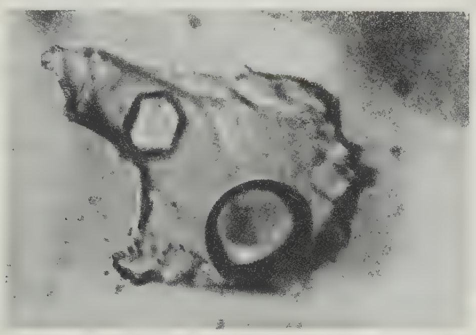


FIGURE 5. Solid-phase (borax) inclusions (quartz, sample IF, x 400)

The result was a series of homogenization-temperature measurements that afforded no basis for any conclusion whatsoever. Inclusions belonging to the same system had different phase ratios and, accordingly, different homogenization temperatures. For example, we obtained 250°, 175°, and 125° C for inclusions within the same system and the inclusion homogenized at 125° contained also a solid phase that would dissolve at 40°C. The scattering of the temperatures and the phase-ratio differences in obviously simultaneously formed inclusions adjoining each other were entirely inexplainable prior to the Lemmleyn-Kliya experiments.

These experiments demonstrated that life of the inclusions continues even after their capture by the crystals. The expression of this activity is found not only in the deposition of substance on the walls of the inclusion-bearing cavities and in the separation of the solid phase, but also in the fact that the inclusions reshape the cavity itself, as they tend to arrive at the equilibrium. This process is especially long in the instance of quartz, since the separation of quartz takes place during the entire mineral-forming process. Consequently, quartz remains soluble in the mother liquor that is subject to capture by the inclusions--and for a very long time. As long as this solubility exists, there remains the possibility of a rebuilding of the cavities containing the inclusions. Figure 6 shows a group of inclu-

FIGURE 6. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample IF, x 180)

sions in smoky quartz. Undoubtedly, this group had a simultaneous origin. Evidently, the two larger inclusions were connected originally by a channel, which ruptured at much lower temperatures. The gaseous bubble of the lower inclusion appears as a black dot on the photograph. Under the microscope, one may notice its movements. The upper inclusion contains a large gaseous bubble that was probably common to both inclusions at one time.

The crystal structure of smoky quartz sample 32F is shown in figure 4. The central part of the crystal is grayish-milky quartz grading into smoky quartz. The latter is overgrown by colorless quartz. The largest number of the inclusions is found in the grayish-milky quartz; the smallest, in the colorless quartz. Distribution of the inclusions in this crystal, as well as in the one previously discussed is apparently the result of its skeletal growth.

Studies of these inclusions first call our attention to the differences in their phasal composition in relation to their clearly simultaneous origin. Some of these two-phase inclusions contain, locally, a solid phase. Liquid carbonic acid could not be detected in any of the inclusions.

Figure 7 shows a group of inclusions in the central part of sample 32F (their location is designated by "1" in figure 4). In this group, two inclusions contain a solid phase; in the third, the large inclusion is two phased and contains no solid phase, very much like the four smaller inclusions. One of them, the lowest, contains no gaseous bubble. If it had a connection with the adjoining inclusion, the connecting channel

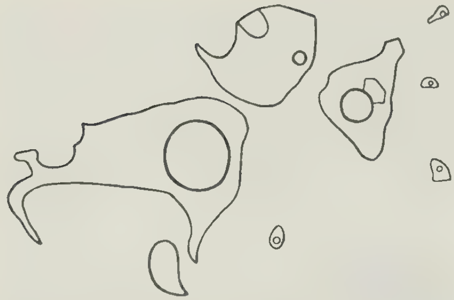


FIGURE 7. A group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 32F)

was too thin to be seen under the microscope.

The phase relationships in the upper two inclusions need to be noted. These two inclusions are nearly of the same size and their gaseous bubbles ought to be of about the same size accordingly. However, the gaseous bubble of the upper-left inclusion is abnormally small and the inclusion's solid phase is nearly twice the size of the solid phase of the right inclusion. Therefore, the homogenization temperatures of these two inclusions are bound to be dissimilar. There can be no doubt that the entire group of the inclusions was formed simultaneously. There can be no question as to the possibility of an intersection of two heterochronic system of fractures. Evidently, the largest inclusion and the upper-left one were one whole, at one time, and were separated already after their capture by the crystal. It is not possible to make any conclusions regarding the temperature at the capture of these two inclusions by the crystal.

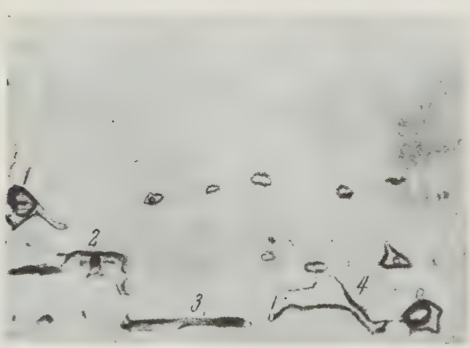


FIGURE 8. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 32F, x 325)

Figure 8 shows a group of inclusions in milky quartz of sample 32F. These inclusions were evidently one whole, a dendritic branch, at the time of their capture. Their later separation from the dendritic branch was heterochronic and was accompanied by a random distribution of the gaseous phase. Thus, for example, inclusion 1 has a large gaseoùs bubble; inclusion 2 had failed apparently to obtain any gaseous phase at all and its gaseous bubble was developed because the cooling of the mineral was continued for a certain period of time; inclusion 3 contains a medium-sized gaseous bubble; inclusion 4 failed to become differentiated. All of its gaseous phase is concentrated in its right and smaller part. Were the process of its differentiation complete, its left part would have had no gaseous bubble, at most, a very small one. Its smaller right part would have had an abnormally large gaseous bubble. On its homogenization, this part would have been filled entirely by gas. It is not possible, in this case, to speak of the temperature at which these inclusions were sealed in the crystal. An analogous example may be seen in figure 9.

FIGURE 9. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 32F, x 335)

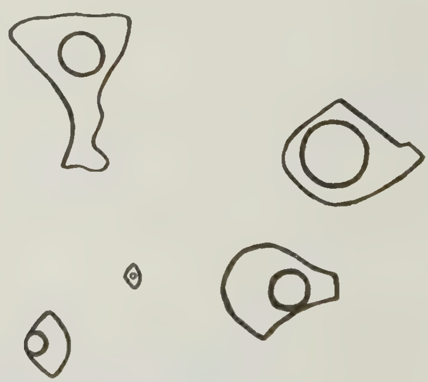


FIGURE 10. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 32F)

Figure 10 shows inclusions in the form approaching the equilibrium. Their phase ratios and, consequently, their homogenization temperatures are bound to be different (their location is marked "2" in figure 2).

FIGURE 11. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 32F)

Figure 11 shows inclusions in colorless quartz sample 32F (their location is marked "3" in figure 4, sample 32F). In this case, also we have a group of inclusions of an apparently simultaneous origin. The gaseous bubble is entirely absent in one of them and its size is out of proportion with respect to the size of the inclusion in the others. If these inclusions are homogenized, we shall obtain a scattering of the temperatures. It is not possible therefore to make any conclusions as to time of their capture by the crystal. These inclusions were not homogenized because specimens are spoiled by cracking in the process. It was desired to preserve these sections as documentary proofs of our conclusions.

We have cited examples illustrating most clearly the phenomen under discussion. The phase-ratio differences and, consequently, the homogenization-temperature differences may be observed throughout the crystal, but with a lesser clarity. It is evident that the separation sequence of the quartz of sample 32F, with the aid of the homogenization temperatures of the inclusions cannot be drawn.

Quartz sample 2F, distinct from the crystals discussed, consists entirely of smoky quartz covered by a thin coating of colorless quartz. Structure of this smoky quartz is distinctly zonal and is expressed in the alternating smoky layers of a different color intensity. The darkest hue is in the layer next to the colorless quartz. The crystal itself is opaque and its internal structure may be observed only in thin sections. This crystal does not contain as many inclusions as the former ones; it is translucent in a thin section. In its lower part, we may observe healed miniature cracks as well as the plane of the primary inclusions which reproduce the zonal structure of the crystal. The fringe of the colorless quartz also contains a number of inclusions along its extent. These inclusions were undoubtedly simultaneous with the crystallization and need be considered as primary accordingly. Locally in the smoky quartz, at the apex and at the colorless-quartz boundary, we find inclusions unrelated to the healing of the cracks. Primary inclusions in the lower part of the crystal are very small, and are so poorly oriented in the section that their observation is rendered impossible.

Inclusions in the colorless quartz could be utilized in the determination of the temperature of its deposition, were it not for the lack of constancy in the phase ratios within the inclusions, as illustrated by samples 1F and 32F. As a further illustration, we are offering here a sketch of a group of inclusions in the colorless quartz (fig. 12).

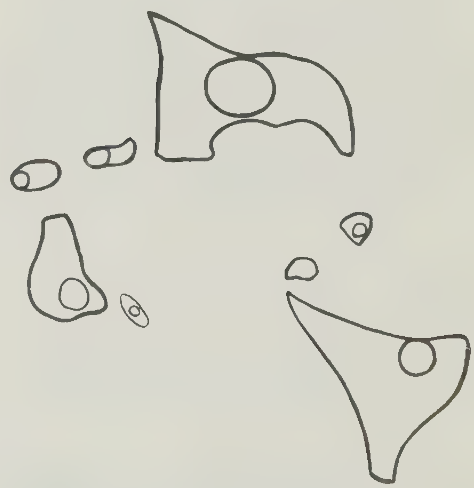


FIGURE 12. Group of inclusions, formed simultaneously, but having different phase ratios (quartz, sample 2F)

It is interesting to note a measure of orderliness in composition of the inclusions. Primary inclusions in smoky quartz, as well as inclusions along the cracks, are all three phased and are solution, liquid carbonic acid, and gas. Inclusions in colorless quartz, on the other hand, and in the areas of smoky quartz bordering on the colorless, are all two phased and are solution and gas.

Quartz sample 8769 is an overgrowth on orthoclase-perthite. The latter is ingrown by quartz ichthyoglypts of uncommonly large size together with platy albite, coarse-platy-lepidolite, and black tourmaline. All these minerals form a coarse-grain aggregate overgrown by fine plates of lepidolite--the "lepidolite boil", in Fersman's [15] nomenclature. The grains of quartz are elongated in the direction of their growth and resemble the ichthyoglypts in their form. Locally, the crystallization of quartz is terminated by the crystallization of albite; both may be terminated simultaneously. In the latter case, the top of the quartz is covered by fine platelets of lepidolite. This quartz is evidently separated concurrently with the zonal crystals described above that generally overgrow the orthoclase and are extensions of the ichthyoglypts which honeycombed the orthoclase. There is a variation in the intensity of the smoky hue of the quartz grains. Their coloration is not zonal, however.

This specimen of quartz is saturated with uniformly distributed inclusions. The absence of their association with certain arbitrarily oriented directions in the crystal--unrelated to its structure and growth zones--is a proof of their primary origin. This latter condition is diagnostic for secondary inclusions. Inclusions distributed uniformly throughout the crystal could have been captured only concurrently with its growth and can be regarded therefore as primary in their origin. Inclusions are chiefly three phased: solution, solid, and gaseous bubble. The solid phase is represented by well-formed crystals of appreciable size. Their form is the same as in the inclusions of quartz sample 1F.

The same kind of crystals within the inclusions were also encountered in other quartz from this locality. The temperature of their dissolution was noted during the homogenization. A complete solution of the solid phase took place between 40° and 50°C [18]. It should be pointed out that the solid phase of the inclusions is represented by borax. In addition, presence of a bituminous substance was detected in the inclusions.

The homogenization temperature was determined by heating in Yermakov microthermochamber. The highest temperature observed was 190°C, while most of the inclusions homogenized at 175° and 150°C. A small number of the inclusions homogenized at 110° to 75°. No regularity in the fluctuations of the homogenization temperatures could be established.

Quartz sample 8771 is colorless and opaque, due to its numerous inclusions. Like sample 8769 previously described, it is found together with platy albite, large plates of lepidolite, and black tourmaline--all forming a coarse-grained aggregate. The quartz has no regular crystalline boundaries. Its paragenetic associations indicate that both the smoky and the colorless quartz, samples 8769 and 8871, respectively, must have been formed during the same stage of mineral formation. Inclusions in this quartz are also distributed uniformly throughout the crystal and, similar to sample 1F, their individual groups resemble the perthite structure of feldspars. Most of the inclusions are three phased: solid, solution, and gaseous bubble.

With the determination of composition of the inclusions in sample 8769, the same determinations were made for the quartz under discussion. Composition of the inclusions proved to be identical with the composition of sample 8769. A bituminous substance was detected, despite absence of the smoky coloration in the quartz. The homogenization temperatures were not determined because of the extremely small size of the inclusions.

Sample 46F is a graphic pegmatite overgrown by crystals of orthoclase, albite-oligoclase, and smoky quartz. The smoky quartz is an extension of an ichthyoglypt, with its prism face contacting the feldspar. A thin section of this specimen was made for a study of the inclusions. The section showed a zonal coloration of the quartz. The bulk of the crystal has a smoky color the intensity of which increases before the deposition of the colorless quartz. A thin margin of colorless quartz is at the surface of the smoky quartz.

Inclusions in this crystal are of two types: with and without liquid carbonic acid. We could not establish any orderliness in their distribution. We had encountered, however, some examples illustrating clearly the evolution of the inclusions after their capture by the crystal.

FIGURE 13. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 46F, x 335)

Figure 13 shows a group of inclusions in the lower part of the crystal. All these inclusions

are two phased, but with unlike phase ratios. They were formed simultaneously, as is evident even in the photograph, as a single system in disequilibrium. They were rebuilt, as they tended to reach equilibrium in the course of the life of the crystal as long as quartz continued to be soluble in the liquid within the inclusion cavities. They separated into two independent inclusions at low temperatures approaching temperatures of the earth's surface. This is indicated by the absence of the gaseous bubble in inclusion 2 the content of which is entirely liquid. Inclusion 1 contains an abnormally large gaseous bubble, in comparison with that inclusion 3 . The size of the latter inclusion is very much like the size of 1. Evidently, the gaseous bubble was common originally to 1 and 2 and the whole of it fell to the lot of 1 after their separation.

FIGURE 14. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 46F, x 335)

Figure 14 shows a group of inclusions in the same quartz. They are situated in the area of transition from the smoky to the colorless quartz, extending chainlike and almost perpendicularly to the zonally colored quartz. With certain assumptions, they may be regarded as following a trace of a rib of the crystal. Regardless of their origin, this group is an outstanding example of a simultaneous formation of inclusions with a widely different phase ratio. This is so evident that no further elucidation is necessary. It is likewise evident that any determinations of temperatures of the mineral formation with the aid of inclusions of this type is fully impossible. There are also inclusions, in the same quartz, whose secondary character is unquestionable. They are shown in figure 15. They are all two phased. With them are also inclusions with different phase ratios.

Sample 41F is a crystal of smoky quartz of the kind that is an extension of ichthyoglypts in the pegmatite and is an overgrowth of feldspar. It also contains inclusions whose phase ratios indicate a long process of rebuilding of the in-

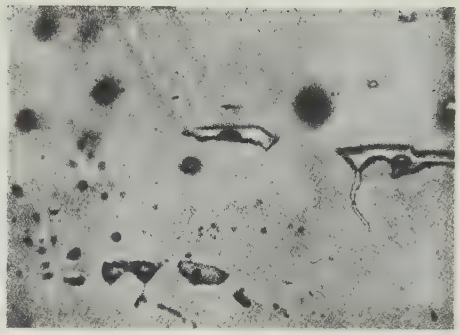


FIGURE 15. Secondary inclusions in quartz (sample 46F, x 335)

clusion cavities. Figure 16 shows three inclusions. One of them contains a large gaseous bubble; the second, a very small one. It is clear that both were interconnected formerly. The third inclusion has no gaseous bubble.

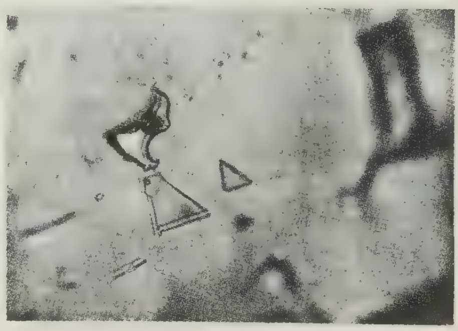


FIGURE 16. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 41F, x 335)

An interesting example of the phase distribution among inclusions in this same crystal is given in figure 17. Inclusion 1 contains a

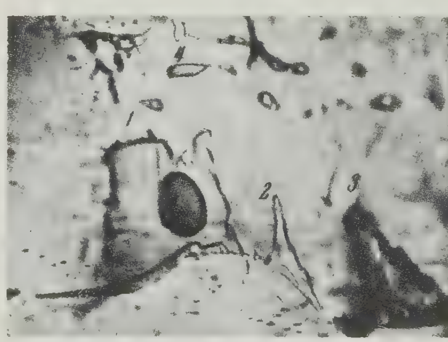


FIGURE 17. Group of inclusions, simultaneously formed, but having different phase ratios (quartz, sample 41F, x 150)

fairly large gaseous bubble; the adjoining 2 contains none; 3 consists entirely of the gaseous phase. All of these inclusions were formed simultaneously.

One could further increase the number of examples, to prove the fact that inclusions in quartz continue to change their form after their capture by the crystal, as long as quartz continues soluble in the mother liquor sealed within the inclusions. An example of this phenomenon, without any explanation, is cited by Skinner [13]. The author studied inclusions in Brazilian quartz. The inclusions were numerous and were uniformly distributed in the crystal. Thin sections perpendicular to the crystal axis were used in the study. The homogenization temperature was measured for all inclusions distributed in four directions in the section. The result was a highly spotted picture that afforded no basis for the author for an establishment of any kind of orderliness in the temperature variations in the homogenization of the inclusions.

Technical limitations of our studies and the small size of the inclusions in the quartz gave us no opportunity to conduct systematic measurements of the homogenization temperatures of a system of inclusions in its entirety. However, it seems to us that the examples here cited are sufficiently clear and convincing. We made an attempt at determining the homogenization temperature for inclusions in 25 crystals of the smoky quartz. An example of these measurements is given for quartz sample 1F. It was not possible to establish any regularity in the homogenization temperatures of inclusions in the quartz question.

QUARTZ OF THE TERMINAL STAGE OF MINERAL-FORMATION

Crystals of grayish-violet quartz may be found, on rare occasions, at Murzinka, and occasionally with a genuine amethyst coloration, as overgrowths on smoky quartz. It is beyond argument that such crystals represent the latest generation of quartz. Their growth takes place in an orderly and in a characteristic fashion. Sample 100F, a druze of quartz grown on graphic pegmatite, is especially interesting, in this respect. The smoky quartz of this druze is heterogeneous; it is overgrown by a thin layer of colorless quartz that is distinctly visible in several crystals. On top of the rhombohedra of the smoky quartz, a rhombohedral growth of fine crystals of amethyst of a highly peculiar structure has its expression in an uncommon configuration of the crystal faces.

The faces of the amethyst consist of seemingly distinct layers with irregular boundaries, with some layers overlapping some others forming boundaries delimiting whole crystal planes. The amethyst seems to consist of individual layers, accretions parallel to the faces of the smoky quartz rhombohedra, and is an interesting example of a layered crystal structure. An analogous manner of crystal growth over the smoky crystals, in the terminal generation of quartz, may be seen in sample 8603. In this case, the grayish-violet quartz overgrowing the smoky quartz is a parallel joint cluster of several crystals.

It is evident that originally several individual very small crystals of the grayish-violet quartz grew on the rhombohedral face of the smoky quartz. These crystals, as in the former case, followed the rhombohedral pattern of the smoky quartz and acquired therefore the parallel orientation, developing their common prismatic faces in the course of their further growth. One large two-point crystal with three heads above, four below, and one common prism developed. Next to this large crystal, the joint cluster, one single crystal grew on a rhombohedron of the same smoky quartz. It had no faces in common with the large crystal and, on coming in contact with the latter, became delimited by the faces of induction. A thin section of this crystal was made with the orientation parallel to its vertical axis and cut through the center of the crystal.

Numerous large odd-shaped inclusions were discovered in this section. Their elongation was perpendicular to the vertical axis of the crystal and, they had a mutually parallel orientation, parallel also to the angle between the rhombohedron and the prism of the crystal wherein they were contained. The cavity walls of the large inclusions were striated, in the direction coinciding with that of the striations on the prism of the crystal itself (figs. 18 and 19).

FIGURE 18. Inclusions in amethyst
This inclusion is the shaded area on the wall of the cavity, oriented parallel with the contact between the prism and the rhombohedral amethyst (x 210).

FIGURE 19. Inclusion in amethyst
This inclusion is the shaded area on the wall of the cavity, oriented parallel with the contact between the prism and the rhombohedral amethyst (x 400).

The form of these inclusions resembled the form of cavities one may observe in skeletal crystals of quartz. Their parallel orientation was also a reproduction of the cavity distribution on the prism faces of the skeletal crystal. Evidently, these inclusions were primary and were formed in consequence of the growth of the amethyst.

These inclusions are two phased, with relatively small gaseous bubbles. Carbonic acid could be detected in none. If we consider this fact together with the fact that carbonic acid could not be detected also in the inclusions in the colorless quartz deposited on the smoky quartz the inclusions which did contain liquid carbonic acid (see description of sample 2F), it becomes evident that the mother liquor in the later stages of the mineral-formation in our locality contained little or none of carbonic acid.

CONCLUSION

Studies of inclusions in quartz from Murzinka showed that the conclusions of Lemmleyn and Kliya, in their investigations of secondary inclusions in artificially grown quartz, are wholly applicable to minerals formed in the earth's crust. It was established that this refers not only to secondary inclusions formed on healing of cracks in crystals but also to primary inclusions developed as the results of defective crystal growth.

In places where nourishment of the crystal is impaired, there develops not one inclusion but a group of inclusions, regardless of the kind of mechanisms responsible for the impairment. Such groups of inclusions represent single systems in disequilibria. These systems, after their capture by the crystal, undergo active reorganizations as they tend to reach the state of a maximum equilibrium between the inclusions and the crystal wherein they are contained. Regardless of the kind of the inclusion, the most stable equilibrium for an inclusion is a negative crystal with faces containing the least amount of free-energy on their surface (Figure 20 illustrates this equilibrium form in quartz.). The degree of equilibrium,

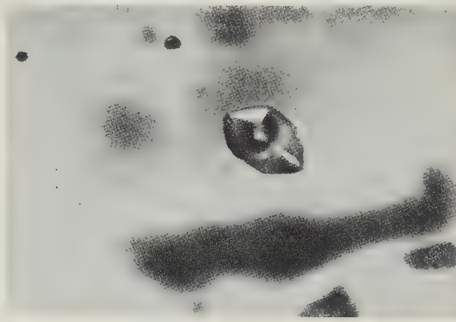


FIGURE 20. Inclusion, in equilibrium, in quartz (quartz, sample 69F, x 335)

for inclusions in minerals, is determined chiefly by the deviation of the activity of the inclusions which, in turn, depends on solubility of the mineral substance in the medium captured and sealed in the inclusion cavities.

The phase ratios in the inclusions may be disturbed in the course of reorganizations within primary inclusions as well as in the course of healing of the cracks in the crystal. Consequently, on heating, the homogenization temperature will be different for different inclusions. This constitutes a very serious limitation of the method by which temperatures of mineral-formation are ascertained from homogenization temperatures of inclusions.

Studies of inclusions in quartz showed that their composition is not uniform. Some three-phased inclusions contain liquid carbonic acid, while others do not, but contain instead a solid phase identified by us as borax [18]. There are also two-phased inclusions consisting of a solution and a gaseous bubble. Within the same quartz crystal, one generally finds three-phased inclusions of only one type (containing either liquid carbonic acid or the solid phase). Two-phased inclusions may be occasionally found with three-phased ones. Composition and phase ratio are not the same for inclusions even within the same system. Three-phased inclusions of both types are found together extremely rarely.

Inclusions in colorless quartz overgrowing smoky quartz as a thin margin and inclusions in amethyst are usually two phased. These facts indicate that composition of the mineral-forming medium was not the same either at the locality or in the course of the mineral-forming process. It was established that there exists

a definite connection between composition of the inclusions and individual features of the paragenetic associations. At Murzinka, two fundamental paragenetic associations occur: 1) smoky quartz-orthoclase-blue topaz-albite-lepidolite and 2) smoky quartz-orthoclase-albite-oligoclase-colorless topaz-gilbertite. Pseudomorphs of gilbertite on cordierite was found only in the second association. Tourmaline and beryl are found in both associations.

For inclusions in the minerals of the first association, boron, as borax, occurs in the solid phase. Minerals of the second associations contain, characteristically, liquid carbonic acid. Effects of microadmixtures may be observed best in topaz [18]. The blue topaz of type I, in Fersman's classification, to which we assign also the "square" topaz and the blue topaz with a well-developed dome, contains solid phase identified by us as borax. The colorless "hexagonal" topaz contains inclusions with liquid carbonic acid. The blue and the colorless topaz were not found together in any single sample from our locality. The sequence of their separation, in reference to the minerals with which they are found (quartz and feldspar) is identical for both. It is evident therefore that their disassociation and occurrence in different parts of the Murzinka pegmatites constitute local features of their origin and are not due to the temperatures of their separation, notwithstanding the opinion of Fersman [15].

Presence of carbonic acid in inclusions within minerals only of a definite paragenetic association and, consequently, only in some parts of our locality is the premise of an opinion to the effect that carbonic acid is not a primary component of the mineral-forming medium of the locality. It was probably introduced from the containing rock.

Marble and dolomite outcrop in the area, as well as peculiar pegmatites in contact with serpentines at Maslyanka and Lugovaya [14]. The earliest report on dolomite outcrops was made by Karnozhitsky (1895) in his description of Startseva mountain which, in its workings, showed a contact of pegmatite with a cryptocrystalline pink-gray dolomite overlying, in an inclined position, the low-lying pegmatite. There is no report of any particular minerals formed in this contact. They are not mentioned by Fersman [14] who confirms the presence of dolomite in the workings. Fersman describes outcrops of limestone along the course of Alabashka river, opposite the village, with the formation of diopside in their contacts, as well as a quarrying of marble 200 m from N [Tr.: "N" probably stands for "New"]. On the right bank of the river, at Alabashka, where, in the contact with a vein of granite, a diopside margin with garnet, phlogopite, actinolite, and sphene is observed.

Presence of carbonic acid in the inclusions observed only in the case of certain definite paragenetic associations of minerals and, consequently, also only for some parts of our locality is conditioned apparently by the presence of outcrops of carbonate-bearing rock. Absence of the typical mineral indicators of the assimilation of carbonate rock leads us to the supposition that we are dealing only with an indirect reflection of the metasomatic process. The scale of this process is suggested by the presence of the characteristic plagioclasite rock in Murzinka area that contains cordierite and ilmenite with plagioclase as well as by the pegmatite in a highly altered serpentine rock, in vicinity of Maslyanka, consisting of plagioclase, green mica, chert, and blue cordierite.

According to Fersman, who visited the site in 1922 during the opening of Mokrusha vein, large dark crystals of quartz, blue topaz, tourmaline, and mica were found at the northern end of the vein. Pseudomorphs on cordierite were characteristic of the vein's southern end. These findings confirm our supposition concerning the spatial differentiation of the paragenetic associations at Murzinka and lead us further to suppose that the influx of carbonic acid and of some other constituents (Mg in cordierite, Ca in oligoclase) may be explained by the presence of tectonic fractures in the area that may have served as channels in the translocations of gases and solutions from parts of the area that were subjected to the metasomatic process.

In any event, absence of materials containing both blue and colorless topaz whose positions in the mineral series of the locality are identical suggests a territorial separation, within the limits of this locality, rather than a crystallization sequence, proposed by Fersman, of first the blue and then colorless topaz.

Composition of inclusions in the minerals was studied only qualitatively, but with some interesting results. Our studies showed that apparently there are no "pure line" mineral occurrences in nature because any rock bordering on the occurrence invariably has an effect on the composition of the mineral-forming media. The mineral-forming media are by no means uniform, even within small distances, nor even within one single vein. This is reflected in the variations in the mineral associations. Among the facts supporting our thesis, there are field observations (in this case, for example, indications that beryl and topaz cannot be found together, that the pseudomorphs on cordierite are limited only to a certain part of the vein and are not found together with the blue topaz) and also composition of the inclusions. Studies of the inclusions in quartz had shown that carbonic acid is present only in inclusions in the smoky quartz. Carbonic acid could not be detected in the colorless quartz overgrowing the smoky quartz and in amethyst growing on top of the smoky quartz.

This is the more curious, since carbonic acid was first detected by Karpinsky [2] specifically in the amethyst from vicinity of Lipovka.

The only possible explanation here is that, in our locality, the volatile components were removed in consequence of some tectonic disturbances, prior to the crystallization of colorless quartz and of amethyst and that the pressure had fallen before the process had entered its hydrothermal phase. The fact that tectonic disturbances had taken place at the time of the transition from the hypercritical and the hydrothermal phases is supported by the presence of crystals and of whole druzes of minerals broken off the walls of the cavities where they grew. They are found lying inside the cavities, the vugs, and they show clearly marks of their healing.

Individual quartz crystals commonly attain the forms of the many-headed growth. Druzes of minerals overgrowing walls of cavities, as "blobs," that can be broken off from their obverse side, as a rule, consist of graphic pegmatite, whose ichthyoglyptic quartz terminates its growth in the form of fine crystals of colorless quartz.

Thus our studies of inclusions in quartz and topaz of Murzinka show that a direct determination of temperatures of the development of our deposit--by homogenization of the inclusions in the minerals--is scarcely possible, although one may obtain some interesting data in such investigations that may help us acquire a more detailed understanding of the mineral-forming process.

REFERENCES

1. Yemakov, N. P., ISSLEDOVANIYE MINERLOOBRAZUYUSHCHIKH RASTVOROV [INVESTIGATION OF MINERAL-FORMING SOLUTIONS]: Khark. Gos. Uv-t, 1950.

2. Karpinsky, A. P., O NAKHOZHDENII V MINERALNYKH VESHCHESTVAKH VYKLYUCHENY ZHIDKOGO UGOLNOGO ANGLIDRIDA [PRESENCE OF LIQUID CARBONIC ANHYDRIDE IN MINERAL SUBSTANCE OF INCLUSIONS]: Gorny Zhurnal, v. 2, nos. 4-5, 1880.

3. __________, YEVGENIYE-MAKSIMILIANOVSKIYE MINERALNYYE KOLI I NEKOTORYYE DRUGIYE [EVGENIE-MAKSIMILIAN MINERAL MINES AND SOME OTHERS]: ZMO, v. 34, no. 1, 1895.

4. Kennedy, G. C., A PORTION OF THE SYSTEM SILICA-WATER: Econ. Geol., v. 45, nos. 7-8, 1950.

5. Kliya, M. O., NEKOTORYYE VOPROSY OBRAZOVANIYA ZHIDKIKH VKLYUCHENY V KRISTALLAKH [SOME PROBLEMS IN THE FORMATION OF LIQUID INCLUSIONS IN CRYSTALS]: Dissertatsiya na soishaniye uchenoy stepeni kandidata geol.-mineral. nauk, Moscow, 1952.

6. Lemmleyn, G. G., SOOTVETSTVUYET LI NABLYUDAYEMYY SOBREMENNYY OBYEM VKLYUCHENIYA PERVONACHALNOMU]IS THERE A CORRESPONDENCE BETWEEN THE PRESENT OBSERVED AND THE ORIGINAL VOLUME OF INCLUSION?]: Akademiya Nauk SSSR, Doklady, v. 72, no. 4 1950.

7. __________, PROTSESS ZALECHIVANIYA TRESHCHNY V KRISTALLE I PREOBRAZOVANIYE FORMY POLOSTEY VTORICHNYKH ZHIDKIKH RKLYUCHENY [THE PROCESS OF HEALING OF CRACKS IN CRYSTALS AND TRANSFORMATIONS IN FORM OF CAVITIES OF SECONDARY LIQUID INCLUSIONS]: Akademiya Nauk SSSR, Doklady, v. 78, no. 8, 1951.

8. __________, PEREMESHCHENIYE ZHIDKOGO VKLYUOCHENIYA V KRISTALLE V NAPRAVLENII K ISTOCHNIKU TEPLA [TRANSLOCATIONS OF LIQUID INCLUSIONS IN CRYSTALS TOWARD SOURCE OF HEAT]: Akademiya Nauk SSSR, Doklady, v. 85, no. 2, 1952.

9. __________, K TEORII ZALECHIVANIYA TRESHCNIN V KRISTALLE I O RAVNOVESNOY FORME OTRITSATELNOGO KRISTALIA [ON THE THEORY OF HEALING ON CRACKS IN CRYSTALS AND ON THE EQUILIBRIUM FORM OF NEGATIVE CRYSTALS]: Akademiya Nauk SSSR, Doklady, v. 89, no. 2, 1953.

10. Lemmleyn, G. G., and M. O. Kliya, NOVYYE DANNYYE OB OTLOZHENII VESHCHESTVAKRISTALLA NA STENKAKH POLOSTI ZHIDKOGO VKLYUCHENIYA [NEW DATA ON THE DEPOSITION OF CRYSTAL SUBSTANCES ON WALLS OF CAVITIES OF LIQUID INCLUSIONS]: Akademiya Nauk SSSR, Doklady, v. 82, no. 5, 1952.

11. __________, OSOBENNOSTI ZALECHIVANIYA TRESHCHINY V KRISTALLE V REZHIME SNIZHAYUSHCHEYSYA TEMPERATURY [PECULIARITIES IN HEALING A CRACK IN CRYSTALS UNDER REGIMEN OF FALLING TEMPERATURE]: Akademiya Nauk SSSR, Doklady, v. 87, no. 6, 1952.

12. __________, IZMENENIYE ZHIDKIKH VKLYUCHENY POD VLIYANIYEM VREMENNOGO PEREGREVA KRISTALLA [CHANGES IN LIQUID INCLUSIONS UNDER THE INFLUENCE OF TEMPO-

RARY OVERHEATING OF THE CRYSTAL]: Akademiya Nauk SSSR, Doklady, v. 94, no. 2, 1954.

13. Skinner, B. J. SOME CONSIDERATIONS REGARDING LIQUID INCLUSIONS AS GEOLOGICAL THERMOMETERS: Econ. Geol., v. 48, no. 7, 1953.

14. Fersman, A. Ye., DRAGOTSENNYYE I TSVETNYYE KAMNI ROSSII [PRECIOUS AND COLORED STONES OF RUSSIA]: Akademiya Nauk SSSR, Komissiya po Izucheniiu Estestvenno-Proizvoditelnykh Sil Rossii, v. 2, 1925.

15. ___________, PEGMATITY [PEGMATITES]: Akademiya Nauk SSSR, v. 1, 1940.

16. Khitarov, N. I., EKSPERIMENTALNAYA KHARAKTERISTIKA USTOYCHIVOSTI KVARTSA I MIGRATSIYA KREMNEZEMA V GIDROTHERMALNYKH USLOVIYAKH [EXPERIMENTAL CHARACTERISTICS OF STABILITY OF QUARTZ AND MIGRATION OF SILICA IN HYDROTHERMAL ENVIRONMENTS]: Sobeshchaniya po Eksperiment. Mineralogii i Petrografii, Trudy 4, v. 2, 1953.

17. Sheftal, N. N., DOKLAD NA VSEZOYUANOM MINERALOGICHESKOM SOVESHCHANII [REPORT AT ALL-UNION MINERALOGICAL CONFERENCE]: cited by G. S. Gritsayenko in Soveshzhaniye po Mineral. i Geokhimii, ZMO, v. 83, no. 3, 1954.

18. Yakubova, V. V., OPYT IZUCHENIYA VKLYUCHENY V MINERALAKH PEGMATITOV MURZINKI (URAL) [AN EXPERIMENT IN THE STUDY OF INCLUSIONS IN MINERALS OF PEGMATITES FROM MURZINKA (URALS)]: Akademiya Nauk SSSR, Mineral. Muzeya, Trudy, 1952, no. 4.

NONFERROUS ORE DEPOSITS IN BULGARIA[1]

by

F. Ekiert and E. Konstantynowicz

• *prepared by the United States Joint Publications Research Service[2]* •

ABSTRACT

Copper, lead, zinc, and iron are the major mineral resources of Bulgaria. Bornite, as well as tetrahedrite, chalcopyrite, pyrite, and colomorphic sphalerite, occur in Triassic dolomitic limestones of the Plakalnica deposit. Porphyry copper deposits occur in Laramide quartz monzonite, granodiorite, and quartz diorite intrusions at Miediet. Other areas of copper mineralization are associated with relatively young volcanic activity and extensive hydrothermal alteration. The zinc and lead deposits are Bulgaria's principal mineral wealth. These occur in the Siedmoichislenie deposit as individually zoned minerals in Triassic dolomitic limestones and as metasomatic replacements probably related to Oligocene rhyolites in the Hercynian-faulted Rhodope massif. Seventy percent of the iron of the Kremikovtsi deposits resulted from the oxidation of siderite to limonite in deformed Triassic sediments. --G. E. Denegar.

INTRODUCTION

During our sojourn in Bulgaria in July 1957 we had the opportunity of becoming familiar with the principal deposits of the ores of zinc, lead, copper, and iron in that country. A more thorough study of some Bulgarian ores has made possible the conduct of an analogy between the Bulgarian and the Polish ore deposits. Such a comparison, although based on a limited number of facts, increases the opportunities of prospecting for polymetalliferous ore deposits in Poland, chiefly in the Lower Silesia region within the area of the Paleozoic complex of rocks belonging to the Sudetens geological unit.

COPPER DEPOSITS

Deposits of copper occur in all ore regions of Bulgaria. The types of these deposits vary in form: there are deposits resembling the sedimentary type (Plakalnica), the porphyry type (Miediet), vein deposits, and impregnations relating to propylitization processes (Panagyurishte region).

The Plakalnica Deposit in Stara Planina

The Plakalnica deposit occurs within the area of dolomitic limestones and Middle Triassic dolomites. It is related to the west-northwest trending Plakalnica fault. This deposit has the shape of a sloping, irregularly thick, overturned letter "S." The mineralized zone is about 150 meters (m) deep, 200 m long, and 50 to 60 m wide. Bornite is the principal mineral. Tetrahedrite and chalcopyrite occur in secondary quantities, and so do, sporadically, pyrite, colomorphic sphalerite, and galena, which often occurs intermixed with bornite.

The genesis of this deposit has not been sufficiently clarified. The majority of geologists regard it as an epigenetic epithermal deposit related to the Plakalnica fault through which hydrothermal solutions had penetrated into the higher zones of the earth's crust. However, there is also no lack of proponents of the sedimentary genetic concept, who claim to see a mineralization of the syngenetic type in the interrelation of the compound zone with the series of dolomitic limestones often containing admixtures of bitumens.

The Miediet Deposit

The Miediet deposit is located in the Sredna Gora mountains in the Panagyurishte region. This deposit is related to Laramide intrusions of quartz monzonites, granodiorites, and quartz diorites. These relatively young intrusions penetrate the highly metamorphosed Paleozoic granites and gneisses forming the Sredna Gora mountains. Among the young intrusions containing a higher content of heavy metals, gray monzonite is especially mineralized. Ore minerals consist of bornite (in the greatest quantity), chalcopyrite, molybdenite, pyrite, and magnetite, as primary minerals, and chalcocite, covellite, bornite, and martite as secondary minerals. Quartz and calcite occur as the epigenetic gangue minerals.

Mineralization by monzonite sulfides is expressed in rock impregnation, filling of latent crevices, and network of vertical little veins with 2 to 3 millimeter thick sulfides where ore minerals are associated with quartz and calcite. The average metal content in ore is: Cu, 0.45 percent (to a depth of 200 m); Mo, 0.008 percent; V, 0.17 percent; Ti, 0.84 percent; Co, 0.002 percent, and Ni, 0.002 percent.

The Miediet deposit is a typical porphyry copper deposit in which the cementation zone is absent owing to morphologic and hydrogeologic conditions and the poor primary deposit reaches the surface. Although the Miediet deposit is a low-percentage one, its considerable resources of metal and ease of exploitation (open-cut mining)

---

[1] Translated from Zeoža rud metali nieželaznych w Bulgarii: Przeglad Geologiczny, 1958, no. 5, p. 229-232.

[2] JPRS (NY) L-383

will cause it in a not too distant future to become the top copper producer in the Bulgarian People's Republic.

The Panagyurishte Deposit

The copper deposits occuring in the Panagyurishte region are related to the comparatively young volcanic activity in that area. The Paleozoic gneisses, granites, granodiorites, and diorites forming a single geologic complex with similar rocks occurring in the about 15 km distant Miediet deposit are intersected by andesites and dacites intrusives of Senonian age.

The mineralized zone is related chiefly to dacites and partially to andesites. This includes the deposits of copper and pyrite and pyrotine [Tr.: ?] in Krasen (exploited deposits) and the Radko and Elshitsa deposits. Maximum mineralization is observed on the southern tectonic contact of dacites with the surrounding rocks represented by granodiorites, and in dacites and their tuffs.

Ore minerals, chalcopyrite, and, in isolated areas, bornite intermixed with chalcopyrite impregnate the surrounding rock and comprise small veins. Among the gangue minerals associated with ore minerals are gypsum, anhydrite, barite, and quartz. The surrounding rock has been subjected to extensive hydrothermal changes: albitization, sericitization, quartzization, and propylitization, as expressed in epidotization, chloritization, and pyritization and in the kaolinization relating to the most peripheral zone of the deposit. Ore bodies have the form of a slope reaching 200 m in length, 40 to 70 m in width, and 700 m in depth. The copper content is about 2 percent, and in some parts may be 8 .

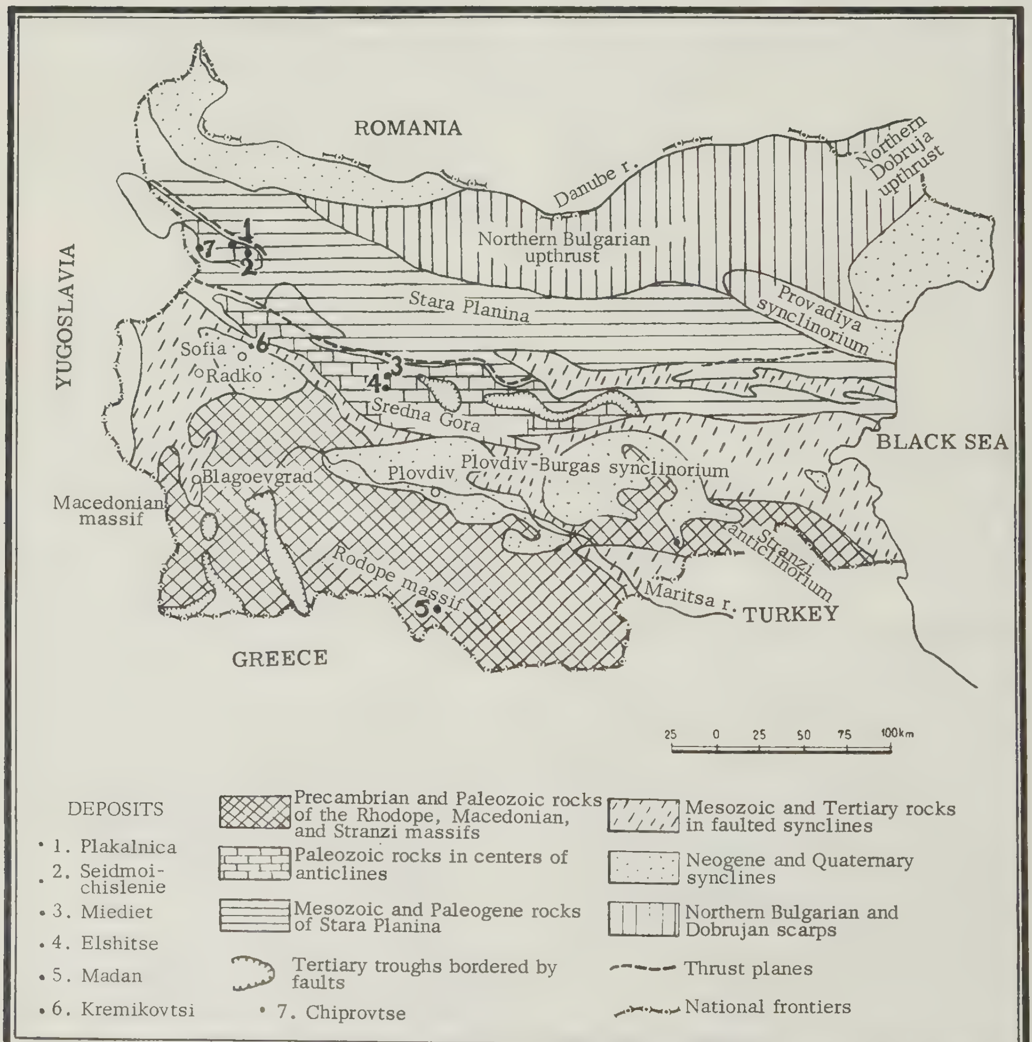


FIGURE 1. Diagrammatic geologic map of Bulgaria (according to M. V. Muratov)

ZINC AND LEAD ORES

Bulgaria's principal wealth with regard to nonferrous-metal resources is its ores of zinc and lead. The largest deposits of these metals in Bulgaria are centered in two ore-bearing regions in the area of Stara Planina in the Siedmiochislenie district (in the vicinity of the Plakalnica copper deposits), and in the southern Rhodopes (Madan district) (fig. 1).

The Siedmiochislenie Deposit

The Siedmiochislenie deposit of zinc and lead ores (fig. 2) is located in dolomitic limestones and Middle Triassic dolomites. The Triassic formations occur in a troughlike structure within the area of a larger tectonic unit, the Berkovskie anticlinorium. At its northeastern end, this trough is truncated by the extensive Siedmiochislenie dislocation beyond which the Triassic formations are in direct contact with the Carboniferous. The ore bodies form a series of lenses arranged in accordance with the contouring of conchoidal limestone sediments situated at various depths. The dimensions of individual ore bodies are as much as 400 m in length and 50-60 m in depth; their thickness varies. In the currently exploited area this thickness does not exceed 5 m. In the areas prospected in the northeastern part of the syncline this thickness reaches 20 m.

The ore minerals occurring in this deposit are: sphalerite, wurtzite (in traces), galena, and pyrite, and, in small quantities, bornite and chalcopyrite.

The distribution of the individual ore minerals in the deposit is marked by a distinct horizontal zonality. There is a central galena zone which is a northwest-trending belt traversing the middle part of the deposit. At both sides of this lead zone there is the adjacent, parallel-running copper zone. The zinc-lead zone forms the peripheries of the deposit. Aside from the horizontal zonality, vertical zonality has also been noted within the area of the copper zone, in this order: galena, galena and chalcopyrite, chalcopyrite and bornite, bornite.

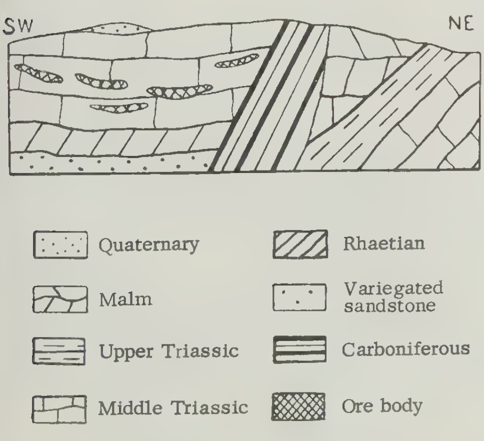


FIGURE 2. Diagrammatic cross section through the Seidmiochislenie deposit

The numerous fissures and cracks present and the larger dislocations contain gangue minerals. The average content of metals in the deposit is as follows: lead, 1.2 percent; zinc, 1.15 percent, and copper, 0.5 percent.

The genesis of this deposit has not yet been clarified and, as in the case of the copper deposit containing galena in Plakalnica, two genetic concepts, the hydrothermal-telethermal and the sedimentary, are applied to it.

The Chiprovtse Deposit

In the Siedmiochislenie region there also occurs a metasomatic zinc-lead deposit in Chiprovtse, in a geologic environment different from those of Siedmiochislenie. The Chiprovtse deposit occurs in the nucleus of the Berkovskie anticline, which is formed by diabases, diabase tuffs, and phyllites with lenticular marble gangues.

A granite intrusion occurs in the western part of the deposit area. In the vicinity of the intrusion contact the Paleozoic rocks in an area of 400 m became transformed into granitic-actinolytic skarns nearer the intrusion and biotitic-epidotic and pyroxene skarns farther from the intrusion. The skarns, nearly always pyrite impregnated, are intersected by numerous quartz veins with molybdenite and, to a lesser degree, pyrite, and, in small quantities, with carbonate-galena ores.

At a farther distance from that intrusion, on the external side of the skarns, ore mineralization was undergone by, chiefly, the limestone lenses in which the following occur in the vicinity of the intrusion (fig. 3): magnetite, siderite, molybdenite, scheelite, pyrite, magnetopyrite, and arsenopyrite. Farther from the intrusion, in the easterly direction, the mineral composition of the ore zone is changed.

In contrast to the minerals characterizing high-thermal processes such as magnetite, molybdenite, and arsenopyrite, the minerals occurring farther from the intrusion contact are characteristic of medium and low temperatures: siderite, galena, sphalerite, pyrite, chalcopyrite, bornite (in traces), and gangue minerals such as ankerite, barite, and fluorite.

The lenticular and chimney-shaped irregular metasomatic ore bodies incline, concordant with the surrounding rocks, in a northwest direction

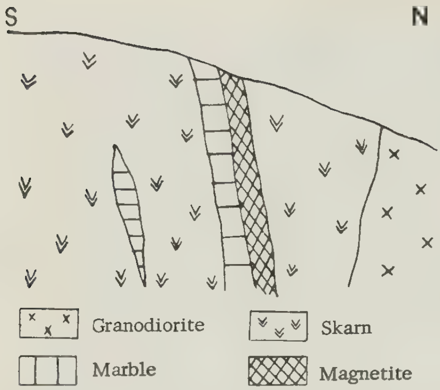


FIGURE 3. Diagrammatic cross section of the Chiprovtse deposit

at an angle of 40°. The dimensions of the individual ore bodies reach the hitherto verified length of 150 m and depth of 450 m, in which connection the character of ore mineralization is not affected by depth. On their longitudinal extent the ore bodies pass over into quartz-calcite veins in the proximity of the sulfide zone of the deposit, and into gangue on the peripheries. The zinc-lead deposit contains about 3 percent of lead, 2 percent of zinc, and 800 to 1,500 grams of silver per ton of ore.

The Southern Rhodope Region

The largest resources of zinc-lead ores in Bulgaria are found on the Rhodope massif, where the Madan deposits are foremost. The zinc-lead deposits occurring in the quartz veins intersecting the Paleozoic gneisses, amphibolites, and limestones faulted during the Hercynian period are related to the Oligocene-Miocene longitudinal faults at a 235° fault angle.

In the Madan region there was verified a total of six fault zones filled with quartz veins with sulfides of zinc and lead. The length of the deposit zones reaches 15 to 16 km, and their thickness varies from 1 to 20 m, and averages 2 to 3 m. Wherever the ore intersects limestones or amphibolites the mineralized zone rapidly expands and passes over into the surrounding rocks at distances of up to 50 m from the fault.

The vein deposit in amphibolites and in the limestones formed by lenses among the metamorphosed rocks passes over into a typically metasomatic deposit (fig. 4). The hitherto verified depth of the mineralized zone reaches 900 m. The paragenetic complex of the minerals occurring in the deposit includes quartz, carbonates, calcite with manganese (rhodochrosite), galena, sphalerite, chalcopyrite, pyrite, marcasite, arsenopyrite, and tennantite.

The following five phases of mineralization

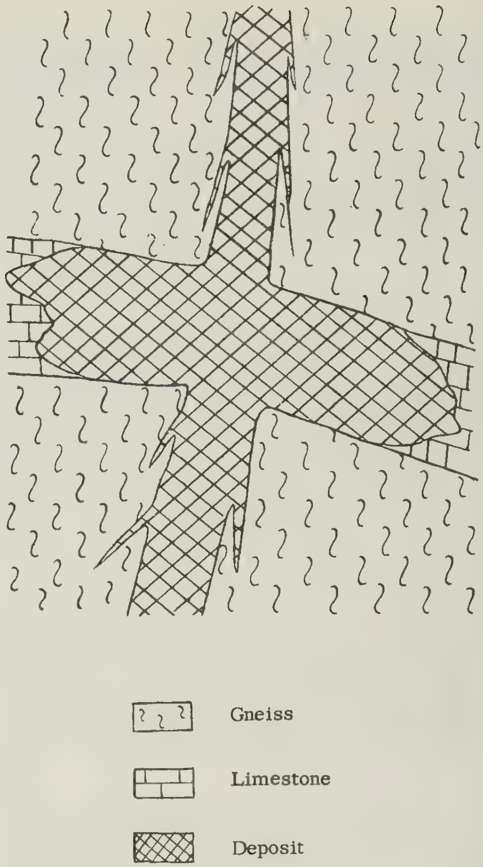


FIGURE 4. Diagrammatic vertical cross section of zinc and lead mineralization in the Madan district

were observed in the deposit: 1) quartz-pyrite; 2) quartz, with galena, sphalerite, and pyrite - the principal phase of sulfide mineralization; 3) quartz-carbonate with sulfides - very little sulfides; 4) quartz - oreless; and 5) carbonate - mainly calcites. It is a noteworthy fact that the older-phase sphalerites contain an admixture of iron, while the younger-phase sphalerite contains an admixture of cadmium. The silver content in galenas ranges from 20 to 70 grams a ton. The quantitative ratio of lead to zinc varies. In veins the lead content ranges from 3 to 12 percent, and the zinc content is nearly always somewhat smaller. In the metasomatic zones zinc (up to 15 percent) predominates over lead (up to 8 percent). Mineralization is probably related to the Oligocene rhyolites occurring westward of the deposit zone in the Madan region.

IRON ORE DEPOSITS

The Kremikovtsi Deposit

At 20 km northeast of Sofia a deposit of iron

and barite ores occurs at Kremikovtsi. Its mineralization is related to the Middle Triassic dolomitic limestone formations (fig. 5). Triassic sediments on the syncline flanks are related to the appearance of two west-northwest trending parallel slip planes, which delimit the northern boundary of the deposit area. Owing to the twofold thrusting of Triassic sediments from the south toward the north onto the Jurassic sediments, the conchoidal limestone formations were deformed into a lens which, at a later period, was metamorphosed by siderite and, to a lesser degree, by barite and hematite.

Barite occurs chiefly in the lower parts of the siderite lens, where siderite-barite nests can be discerned. Substantial quantities of barite are also found in unaltered limestone formations occurring in the siderite. Hematite forms irregular small lenses in the middle and upper parts of the deposit, mainly in its western part. The other, quantitatively much smaller, minerals occurring in the deposit are chiefly pyrite, galena, sphalerite, and chalcopyrite.

Owing to subsequent oxidation processes, the major part of the siderite was transformed into limonite, which accounts for 70 percent of all iron ores in the deposit. The siderite ore accounts for 20 percent, and the hematite ore, 10 percent. These iron ores are characterized by their large content of manganese, barite, and lead. The quantitative share of elements in the three types of ore is as follows:

Type of Ore	Fe (%)	Mn (%)	$BaSO_4$ (%)	Pb (%)
Siderite	24	5	21	0.36
Limonite	32	6.5	19	0.64
Hematite	48	1	8	0.14

The content of $SiO_3 + Al_2O_3$ averages 5 to 6 percent. The content of CaO + MgO averages 5 percent.

The deposit was verified in an area of about 1.5 square km at an average thickness of 80 m and average depth of 80 m. Its mineralization

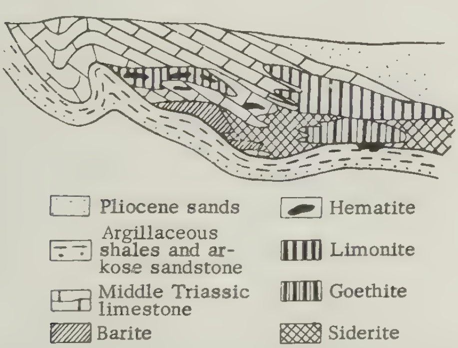


FIGURE 5. Diagrammatic vertical cross section of the iron deposit at Kremikovtsi

was, according to Bulgarian geologists, related to the younger manifestations of the Laramide-phase magmatism, and perhaps to the Witosza plutonism.

CONCLUSION

In concluding this brief survey of the principal deposits of zinc, lead, copper, and iron in Bulgaria, emphasis should be placed on a definite geologic similarity between some Bulgarian and Polish deposits. From this standpoint, the Polish ore geologist should be most interested by the Siedmiochislenie deposit.

The German geologists, who ascribe a sedimentary origin to most of the zinc-lead ores of the Triassic period in the European metallogenic province, including also the Polish deposits in Upper Silesia, very often cite the Siedmiochislenie deposit as the example of a sedimentary deposit. Similarities between the zinc and lead ores of Upper Silesia and the Siedmiochislenie deposit can be discerned in: 1) the close relation between the mineralized zone and, chiefly, the Middle Triassic sediments, which in Poland and Bulgaria evolve into carbonate facies (limestones and dolomites); 2) the irregular ore lenses and nests observed in the Siedmiochislenie deposit, which correspond to the peripheral sectors of deposit zones in Upper Silesia (for example, the Nowy Dwor deposit of [Tr.: one word illegible] in the western part of the Bytom trough, and the deposit in the Kalety-Miotek region); and 3) the absence, within the deposit area, of manifestations of magmatism to which the mineralization of Triassic sediments could be related.

The differences evident at a closer study of both types of deposits pertain to the petrographic composition of ores and the qualitative and quantitative share of individual minerals in ores. The Siedmiochislenie deposit contains besides galena and sphalerite substantial quantities of copper sulfides (chalcopyrite and bornite) which are absent in the Upper Silesian deposits.

The galena from the Siedmiochislenie deposit is compact and fine grained. It differs from both the coarse-grained galena in Polish deposits, which fills the fissures in dolomites, and the loose, fine-grained galena associated with colomorphic zinc blende. Likewise, the quantitative ratio of lead to zinc differs in each type deposit. In the Upper Silesian deposits it ranges from 1:3 to 1:8, while in the Siedmiochislenie deposit it approximates 1:1 with some excess of lead, which would more or less correspond to the Upper Silesian northern-marginal deposit zone (the Tarnow mountains region), where the Pb:Zn ratio is at its highest.

It is to be emphasized that the occurrence of similar deposits in conchoidal limestone sediments in Bulgaria and Poland is no mere accident. Such similar deposits also occur in the Alps

(Raibl, Bleiberg), and in West Germany (Mechernich, Maubach), and sporadically increased contents of, chiefly, lead and, to a lesser degree, zinc are observed in conchoidal-limestone sediments in Germany as a whole. In recent years, the occurrence of a deposit of barite with galena was verified within the area of Triassic sediments in the vicinity of Tureza (Romania). Hence, Triassic sediments in Europe constitute an eminent formation for the long-range prospecting for deposits of ores of nonferrous metals and iron (for example, the Kremikovtsi deposit).

Also, the zinc-lead ores of the southern Rhodope deserve particular attention of Polish geologists.

ON THE ACCURACY OF SMALL-SCALE MAPS [1]

by

A. I. Shabanova

• prepared by the United States Joint Publications Research Service •

ABSTRACT

Errors on the order of ± 0. 5 mm are introduced in the compilation, preparation, printing, and mounting of small-scale maps. Approximately 70 percent of the error occurs in compilation; only 15 percent in printing and mounting. Mean square errors are approximately the same for maps compiled by the method of copying squares and for those compiled from blueline prints. The accuracy of plotting rivers and roads is somewhat higher than the accuracy of compiling populated places, elevation points, and wells. Technological improvements apparently should be sought for the mechanization of compilation and substitution of blueline paper by another material less subject to distortion. --G. E. Denegar.

INTRODUCTION

In order to reveal and eliminate some "tight" points from the technique of map making, as well as to utilize more rationally various instruments in map making, one has to know the actual accuracy of the published maps and the errors made at individual stages of the map making process. In 1955-1956 the cartographic division of TsNIIGAiK [Tr.: Tsentralnyy nauchno-issledovatelsky institut geodezii, aerosyemki i kartografii: Central Scientific Research Institute of Geodesy, Aerial Surveying, and Cartography] conducted similar research on a series of small-scale maps, which constitute one of the basic types of cartographic production. General geographic reference maps at scales of 1:1, 000, 000 to 1:7, 500, 000 were analyzed. These maps are most valuable for use in cartometric work and as basic cartographic material for the compilation of other small-scale maps.

The research was conducted according to the method proposed by Professor N. A. Urmayev. This method makes it possible to find the accuracy of the analyzed map. It also makes it possible to separate from the results of the measurements all systematic errors which appear in the process of map making as well as in the process of taking the control measurements, and it also makes it possible to analyze them.

Since the purpose of the research was to satisfy the demands of the map-making technology, only the planimetric positions of the various points on the map were investigated, and only those positions which cannot change by generalization of so-called "rigid" or "control" points.

The method of the analysis as well as the performance and results of the work, are stated below.

THE CONCEPT OF HORIZONTAL (PLANIMETRIC) ACCURACY AND THE METHOD OF DETERMINING IT

Let us define horizontal (planimetric) accuracy of a map as the accuracy with which various elements of the map are plotted with respect to its plane. We shall characterize this accuracy by the values of displacement of the control points on the map from their true position, that is, by the difference in the rectangular coordinates of the points x, y actual, and X, Y true. The coordinates x, y are obtained by measuring them directly on the map with the help of a "coordinatograph." As the true position of the points on the map being analyzed, we can accept their position on the large-scale (control) map. At that, scale differences must be such that the possible errors of the control map are within the graphic accuracy of the map being analyzed. The coordinates X, Y are calculated from the formulae of the projection of the map under analysis after the necessary coordinates have been obtained from the control map.

If the corrections for the projection differences of the given sheet of the map under analysis are constant or are proportional to the coordinates of its points, then it is not necessary to calculate the true coordinates X, Y by the methods indicated. In that case, it is sufficient to measure the rectangular coordinates X, Y on the control map and to consider the corrections in them for the projection differences as a systematic error for the given sheet, and to compute them along with the other errors as shown below.

The difference obtained in such manner $\sigma_{x'} = x - X$ and $\sigma_{y'} = y - Y$ will consist of the errors made in the process of map making, in the position of the measured points, and the errors made in measuring the coordinates.

---

[1] Translated from O tochnosti kart melkogo masshtaba: Geodesiya i Kartografiya, 1957, no. 10, p.36-44. JPRS L-1389-D.

The character of both types of errors could be incidental as well as systematic. In order to have a correct understanding of the accuracy of the map, a distinction should be made between both types of errors and the systematic errors should be eliminated in the future.

In the given case, the systematic errors could be considered as the result of various deformations of the map. Since the values of the systematic errors are relatively small, the method proposed by Professor N. A. Urmayev could readily be used to determine them. In that method the actual coordinates are equated to the true coordinates after the following corrections are made:

$$x + \Delta x = X$$
$$y + \Delta y = Y \qquad (1)$$

where $\Delta x = a_o + \alpha x + \gamma y + \delta y$

$$\Delta y = b_o + \beta y + \gamma x + \delta x. \qquad (2)$$

Here

a_o, b_o = rigid shift along the coordinate axis,

α, β = coefficient of extension (distension) along the coordinate axes,

γ = coefficient of deformation of the displacement itself (an elementary square becomes a rhomb),

δ = coefficient of rigid rotation around the origin of the axes.

In the given case, the terms a_o, b_o, δy, and δx in the formulae (2) are corrections in the coordinates of the control points for the insufficiently precise orientation of the investigated map made by measuring the actual coordinates, and for the non-registration of the colors (tints) in printing. The terms αx, βy, γy, and γx are corrections for the deformation of the paper and also for the difference in the graduation of the scales on the coordinatograph and the nonperpendicularity of these dials. (Terms a_o, b_o, αx, and βy also include corrections for the projection differences of the map under analysis and the control map.)

However, in reality, the equation (1) will not hold since the incidental errors are present. Therefore, the coefficients a_o, b_o, α, β, γ, and δ are determined under the conditions of the minimum sum of the squares of the residual (in the given case incidental) errors, from the solution of the following system of equations of errors given for the series of control points:

$$a_o + \alpha x_i + \gamma y_i + \delta y_i + lx_i = \delta x_i$$
$$b_o + \beta y_i + \gamma x_i - \delta x_i + ly_i = \delta y_i \qquad (3)$$

where: $lx = \sigma_{x'} = x - X$
$ly = \sigma_{y'} = y - Y$

After the corrections found are excluded, the coordinate differences

$$\sigma_x = \sigma_{x'} - \Delta x$$
$$\sigma_y = \sigma_{y'} - \Delta y \qquad (4)$$

will now represent the components only if incidental errors that are in the position of the control points as the result of all the phases of the map-making process, and in taking control measurements. But the incidental errors can be neglected since they are measured by the coordinatograph.

The obtained differences σ_x and σ_y will, of course, vary within certain limits. Therefore, it is more convenient to represent the horizontal (planimetric) accuracy of the map, generally, as the value of the mean square error

$$m = \pm \sqrt{\frac{[\sigma^2]}{n}} \qquad (5)$$

where $\sigma^2 = \sigma_x^2 + \sigma_y^2$, and n is the number of control points.

The number of control points necessary for obtaining reliable results in determined from the assumed maximum value of the mean square error m and the accuracy of m' with which the following error must be known:

$$m' = \frac{m}{\sqrt{2n}} \qquad (6)$$

It is determined on the basis of the preliminary investigations that in the given case the mean square error does not exceed $\pm$ 0.7 mm. In order to determine it with an accuracy not lower than the graphic, it is necessary to have 20-25 control points. It is more convenient to conduct the analysis along the basic elements of the map: grid, populated places, hydrography, and road network.

For the control points one should select points that can be recognized without any doubt on the control map: points of grid intersection, geometric centers of populated places with distinctly depicted boundaries, confluences of rivers and their tributaries, road intersections, etc. The control points should be distributed as evenly as possible along the whole plane of the map under analysis. The points which have to be displaced because of generalization or certain other considerations of the type discussed above cannot be used as control points because they will give a distorted impression of the accuracy of the map compilation.

THE ANALYSIS AND ITS RESULTS

On the basis of the above-discussed methods of determining the accuracy of the map, the following work program has been adopted:

1. The selection of the control points for all the elements under analysis contained in the given map.

2. a) Determination on the control map of the geographic coordinates ϕ and λ of these points and computation of their rectangular coordinates X, Y in the projection and scale of the map being analyzed. b) Determination, on the control map, of the rectangular coordinates X, Y of the selected points in case the difference between the coordinates of the points in the projections of the map under analysis and the control map is not large and equal to a constant value or proportional to the coordinates of the points on the maps.

3. Measurement of coordinates x, y on the map under analysis.

4. Computation of the coordinate differences

$$\sigma_{x'} = x - X \text{ and } \sigma_{y'} = y - Y$$

5. Computation of the value a_o and b_o and the coefficients of the remaining systematic errors contained in the map. This entails the following: a) construction of equations of error based on the results of the measurements of points of intersection on the grid, assuming that the systematic errors inherent in the geographic grid will also be inherent in all the other elements of the map, because the latter are usually plotted with reference to the grid; and b) construction and solution of normal equations (evaluation of the quality of the unknown values by the methods of gravitational coefficients).

6. Computation of the corrections for the systematic errors in the coordinates of the control points of all analyzed elements of the map.

7. Computation of the coordinate differences σ_x and σ_y, which are free from systematic errors.

8. Computation of the mean square error in plotting each of the analyzed elements.

The analysis performed according to this program consists of two phases:

1. Determination of the mean square error in the position of the points on the published map copies.

Seven maps were analyzed. Two of them are 1:2, 500, 000 maps of the northwestern and southwestern areas of the European U. S. S. R., which are general geographic reference maps from the Atlas Mira [Tr.: World Atlas] edited by GUGK [Tr.: Glavnoye upravleniye geodezii i kartografii: Main Administration of Geodesy and Cartography], 1954, and compiled in conical equiangular projection by the method of copying by squares. The remaining five maps make up the European part of the U. S. S. R. The scale is 1:7, 500, 000 in conical equiangular projection and the sheets of the 1:1, 000, 000 maps are J-41, M-36, O-35, and P-36, all of which were compiled from blueline prints. In all seven cases, large-scale maps of recent editions served as control maps. In comparison with the analyzed maps, the difference in scale was 10 times and more.

As an example, a series of computation made in analyzing sheet M-36 of the 1:1, 000, 000 map is given below.

Within the limits of sheet M-36, the differences in coordinates between the control map and the map under analysis do not exceed the graphic accuracy. Therefore, the computations are performed according to the point 2(b) of the aforementioned program.

In preparing table 1, the left side was completed first, specifically, columns 1-4. Columns 2 and 3 show mean arithmetical values of the coordinate points measured by two readings. Then the equation of errors (3) and the set of the normal equations were set up. In solving this set, the following values, which characterize the systematic errors in the coordinates of the points on the given map, were obtained:

$$\begin{aligned} a_o &= +\ 0.155 \pm 0.030 \text{ cm} \\ b_o &= +\ 0.169 \pm 0.030 \text{ cm} \\ \alpha &= -\ 0.00222 \pm 0.0004 \\ \beta &= -\ 0.00326 \pm 0.0004 \\ \gamma &= -\ 0.00086 \pm 0.003 \\ \delta &= -\ 0.00071 \pm 0.0003 \end{aligned} \qquad (7)$$

The right side of the table was filled next. The corrections were computed (columns 5, 6, 7, 8) and the coordinate differences σ_x and σ_y (column 9), which have no systematic errors in the position of the intersecting points of the grid of the map under analysis.

As we mentioned before, the values (7) are used to compute corrections in the coordinates and other analyzed elements. Similar computations are made for all basic elements of the above-named seven maps. Altogether, more than 600 points were measured and compared with the true coordinates, which makes it possible, with a sufficient degree of confidence, to judge the horizontal (planimetric) accuracy of the analyzed maps. The results of the measurements of all maps are given in table 2.

It is necessary to note that the accuracy in the plotting of roads of various classifications was found to be the same. Therefore, the table shows only one figure for each map. The accuracy in the plotting of populated places located along river banks was the same as the accuracy of those located away from them. Mean square errors in the position of both varied within the

TABLE 1. Determination of the mean square error in the position of the intersecting points of the grid

x cm, y cm	X cm, Y cm	$\sigma_{x'}, \sigma_{y'}$	a_0, b_0	αx, βy	γy, γx	δy, δx	σ_x, σ_y
76.534	76.450	+ 84	+155	-170	-31	-26	+12
36.268	36.312	- 44	169	118	66	+55	- 4
76.780	76.654	+126	155	170	61	-50	0
70.602	70.520	+ 82	169	230	66	+55	+10
65.410	65.338	+ 72	155	145	31	-26	+25
35.960	36.021	- 61	169	117	56	+46	-19
43.406	43.429	- 23	155	96	24	-20	- 8
28.050	28.086	- 36	169	91	37	+31	+36
43.166	43.172	- 6	155	96	30	-25	- 2
35.362	35.414	- 52	169	115	37	+31	- 4
43.020	43.001	+ 19	155	96	49	- 40	-11
57.317	57.276	+ 41	169	187	37	+31	+17
43.162	43.143	+ 19	155	96	56	-46	-24
64.636	64.574	+ 62	169	211	37	+31	+14
43.408	43.350	+ 58	155	96	62	-51	+ 4
71.952	71.877	+ 75	169	235	37	+31	+ 3
31.900	31.892	+ 8	155	71	49	-40	+ 3
57.464	57.432	+ 32	169	187	28	+23	+ 9
32.046	32.006	+ 40	155	71	56	-46	+22
64.926	64.868	+ 58	169	212	28	+23	+10

(Ed.: Columns 2-9 only are here reproduced, the original column 1 presumably cited specific points on the map.)

$m = \pm 28$

Note: Here and in the following the coordinate differences and all corrections and values of the mean square errors are given in thousandths of a centimeter.

TABLE 2. Mean square errors in the planimetric position of the control points of the published copies of small-scale reference maps

Maps	Grid	Populated places	Rivers	Roads	Spot elevations	Average for all elements exclusive of the grid*
1 Northwestern European part of the U. S. S. R., 1:2,500,000	18	56	39	44	-	47
2 Southwestern European part of the U. S. S. R., 1:2,500,000	19	67	44	43	-	53
3 European part of the U. S. S. R., 1:7,500,000	20	67	66	57	-	63
4 Map of 1:1,000,000 scale sheet J-41	33	66	66	48	50	58
5 M-36	28	69	45	56	57	57
6 O-35	16	56	53	64	70	61
7 P-36	16	50	50	46	63	53
Average for all maps	22	62	53	52	60	56

* Mean square errors in the position of individual elements are obtained with an accuracy up to 10-15 percent; average for all maps and all elements, up to 5-7 percent.

limits of the computation accuracy.

The deformation of the paper of the analyzed copies of the maps, as determined by the coefficients, did not exceed $\alpha = 0.003$, $\beta = 0.003$, and $\gamma = 0.001$.

2. Determination of mean square errors in the position of various points on the map made at different stages of its making.

The compiler's copies, editor's original copies, and hochure proofs [Ed.: printers' copies], or published copies were analyzed. The coordinates of about 1,300 points were measured and compared with the true coordinates

For the purpose of ascertaining the accuracy

of compilation, the following compiler's originals were investigated: a) sheet H-30 of a 1:1,000,000 map, compiled from blueline prints, which were made from French 1:500,000 topographic maps of Africa in conical equiangular Lambert projection and in the projection of the international map; b) sheet H-31 of the same map, compiled from blueline prints which were made from sheet H-31 of the 1:1,000,000 map, 1948 edition; c) sheet G-31 of the same map, compiled from blueline prints which were made from 1:200,000 topographic maps in conical equiangular Lambert projection; and d) map of the southern part of Capetown Province in conical equiangular projection, scale 1:3,000,000, compiled by the method of copying squares from sheets of a 1:500,000 French topographic map of the Union of South Africa.

Because the compiler's manuscripts were not available, editor's originals of two Atlas Mira maps were also investigated: the northwestern and the southwestern area of the European part of the U. S. S. R., scale 1:2,500,000, compiled by the method of copying squares. These originals can also characterize the accuracy of the compilation if the errors in mounting are eliminated.

The analysis was performed by the abovementioned method, the only difference being that the "true" position of the control points was taken from the cartographic source material which was used as base for the compilation of the given map.

the accuracy of the grid on the coordinatograph is known.

Similarly, editor's originals, hochure samples, or published copies of the maps were analyzed. In each case, the positions of the control points shown in the preceding stages of the map-making process were taken for the "true" position. The results of the analysis are listed in table 4. The mean square values of the error introduced into the map during preparation are reduced to the scale of compilation and publication.

CONCLUSION

Thus, as a result of the accomplished work, it has been determined that the mean square error of the horizontal position of the control points on 1:1,000,000 to 1:7,500,000 maps is $\pm$(0.5-0.6) mm.

About 70 percent of this figure represents errors made during the compilation of the maps and about 15 percent errors made during mounting and printing.

The mean square errors for maps compiled by the method of copying squares are approximately equal to those compiled from blueline prints, namely, $\pm$ 0.4 mm. If, in the first instance (compilation by copying squares), this tolerance be considered as approaching the ultimate; then in the second instance (compilation from blueline prints) the accuracy in our opinion should be considered too low. The only explanation for such a low accuracy of map compilation from blueline prints is the inferiority of mounting and drafting. There are objective possibilities for increasing the accuracy in this instance.

TABLE 3. Mean square errors in the relative position of control points on originals

	Maps	Method of compilation	Populated places	Rivers	Roads	Spot elevations	Wells	Average for all elements
1	H-30	from blue-line prints	48	34	26	-	51	41
2	H-31		40	36	32	32	46	38
3	G-31		48	25	42	45	44	42
	Average for 3 sheets		46	32	34	39	47	40
4	Cape of Good Hope Province	copying squares	44	39	46	-	-	43
5	Northwestern areas of European part of the U. S. S. R.		51	28	32	-	-	38
6	Southwestern areas of the European part of the U. S. S. R.		57	40	35	-	-	48
	Average for 3 maps		51	36	38	-	-	42

Mean square errors in the position of the control points on the compilation originals in relation to their position on the cartographic source material is shown in table 3.

In table 3 there is no information about the grid, since it is inexpedient to compare the positions of the points of intersection of the grid on the compilation original with their position on the cartographic source material. However,

The accuracy of plotting the analyzed elements of the maps is approximately the same;

however, the accuracy is somewhat higher in the compilation of rivers and roads and somewhat lower in the compilation of populated places, elevation points, and wells. In the case of populated places this condition may be the result of some vagueness in determining boundaries and centers of the populated places. There are no objective reasons for the decrease in the accuracy of spot elevation and wells.

TABLE 4. Mean square errors made in the position of control points

	Maps	Grid	Populated places	Rivers	Roads	Spot elevations	Wells	Average for all elements
	In the process of preparing the map							
1	H-30	14	23	20	20	18	13	19
2	H-31	19	13	25	21	13	13	17
3	G-31	20	22	23	18	17	19	19
	Average for 3 sheets	18	19	23	20	16	15	18
	In the process of printing the map							
1	H-30	13	15	20	21	11	18	16
2	H-31	15	14	21	16	13	12	15
3	G-31	19	15	17	15	21	14	16
4	Northwestern areas of the European part of the U. S. S. R., scale 1:2,500,000	18	17	20	15	-	-	18
5	Southwestern areas of the European part of the U. S. S. R., scale 1:2,500,000	23	20	24	17	-	-	21
	Average for all maps	18	16	20	17	15	15	17

As shown in table 4, errors introduced during the mounting process in the positions of various points on the map usually do not exceed the graphic accuracy.

The errors made in the position of various points on the maps during printing are also within the limits of the graphic accuracy. However, it should be noted that we are discussing incidental errors. The systematic errors could be greater because of the misregistration of tints and deformation of the paper. In the course of this analysis, no misregistration of tints affecting the quality of the map was discovered. The largest distortion in the paper of the printed copy of the map was approximately 0. 3 percent, which must be taken into account when precise measures are made.

The information obtained about the accuracy of the map, of course, is incomplete, but even this information is of practical value. The process of map making considered in this work is most widely used in cartographic production. At the same time, the results of the analysis show that in this case additional errors occur which are several times greater than the errors in the cartographic material. It is obvious that this process will not be used in the making of maps designed for cartometric work. Technological improvements apparently should be sought along the lines of a mechanization of compilation work and substitution of blueline photo paper by another material less subject to distortion.

In other cases, not requiring greater map accuracy (taking into consideration the purpose of the map), this situation should be taken into account, and no unjustified accuracy should be demanded at any stage of the map-making process. While at present, for instance, excess accuracy is often demanded in the computation of the coordinate points of the grid, or too rigid a tolerance is set for the points within the converted areas, this attitude narrows the field of application of conversion and increases the cost of the map.

The significance of the analysis is not limited to the problems of map-making processes. The actual accuracy determined for some widely used small-scale maps can be used in various cartometric projects.

NEW DATA ON THE STRATIGRAPHY OF MESOZOIC SEDIMENTS IN THE WESTERN TRANSBAIKAL REGION [1]

by
S. M. Zamarayev and G. R. Kolosnitsyna [2]
• translated by Salih Faizi •

ABSTRACT

Continued mineral exploration in western Transbaikal has resulted in further stratigraphic investigation of Mesozoic sediments in that area. Martinson, on the basis of fauna collected, assigned the Gusino-Ozersk bituminous shales to the middle of the Lower Cretaceous. Stratigraphically and paleontologically, the shales, containing a large number of phyllopods, insects, and fish, resemble transitional Upper Jurassic-Lower Cretaceous Mongolian sediments. It is possible that the boundary between the Jurassic and Cretaceous in this region is not a line, but a transitional zone of apparently small width. --G. E. Denegar.

Exploration for coal, oil, and other minerals in the western Transbaikal region has attracted the attention of geologists to the stratigraphy of its Mesozoic sediments. G. G. Martinson [2, 3] found major groups of fresh-water fauna of various ages in the continental sediments of eastern Siberia. On the basis of these fauna groups, he was able to determine a number of layers. The question of the age of the bituminous shales and the stratigraphic position of some groups of fauna in the Gusino-Ozersk sediments of the western Transbaikal region, which include several layers of upper Mesozoic sediments, must be reviewed.

It is believed that the original materials from which the bituminous shales were formed accumulated slowly within an area undergoing peneplanation. The development of these peneplains, their tectonic alteration, and their duration help us to understand the geologic history of the Transbaikal region, and particularly the nature of the tectonics.

It is now evident that the downwarping of the Mesozoic basins in the Transbaikal region took place simultaneously with the elevation of the adjacent mountain ranges; the opposing movements were balanced in some places, while in other places elevation or downwarping occurred independently. The basins and ranges existed for a long period as the major forms of relief. As the upwarping of the ranges subsided, weathering reduced the relief of the area and resulted in the accumulation of fine clastic, chemical, and biogenic sediments.

The occurrence of bituminous shales in the Transbaikal region, Mongolia, and northern Manchuria indicate that the paleogeographic conditions during certain periods of geologic history in parts of these broad areas have been identical and were inherited from previous tectonic activity. As a result of this activity, these broad areas underwent peneplanation either simultaneously or at slightly different times, but by the same processes.

The following groups of fauna were determined in the bituminous shales: fish, Licoptera middendorfi Mull. and Licoptera fragilis Gucj.; insects, Ephemeropsis trisetalis Eichwaldi; and gastropods, Bithynia sp.

As a result of his studies, Martinson concluded that the bituminous shales in the entire Transbaikal region were formed in the middle of the Lower Cretaceous.

A study of some stratigraphic sections permits us to establish that the bituminous shales and the synchronic argillites composed principally of quartz sandstones and silts were actually formed during relatively short periods, but not so short as assumed by Martinson.

The section of Mesozoic sediments recovered from a drill hole on the left side of the Khilok valley, 3 kilometers (km) from the river bed and facing the mouth of the Tugnuy river in the southwestern part of the Tugnuy basin, is especially interesting in this respect. The section is composed of silt-argillite-sandstone which contains beds of thin platy shales; the greatest part of the shales is bituminous (fig. 1).

The shales contain a large number of phyllopods, insects, and fishes. These groups of fauna occur together, in places even within the platy shales. The number of both species and forms within each species varies in different horizons of the section.

With the advice of N. I. Novozhilov, we determined the following group of phyllopods:

---

[1] Translated from Novyye dannyye po stratigrafii mezozoyskikh otlozheny Zapadnogo Zabaykalya: Novosti Neftyanoy Tekhniki, Geologiya, 1958, no. 8, p. 3-7.

[2] Vostsibneftegeologiya Trust.

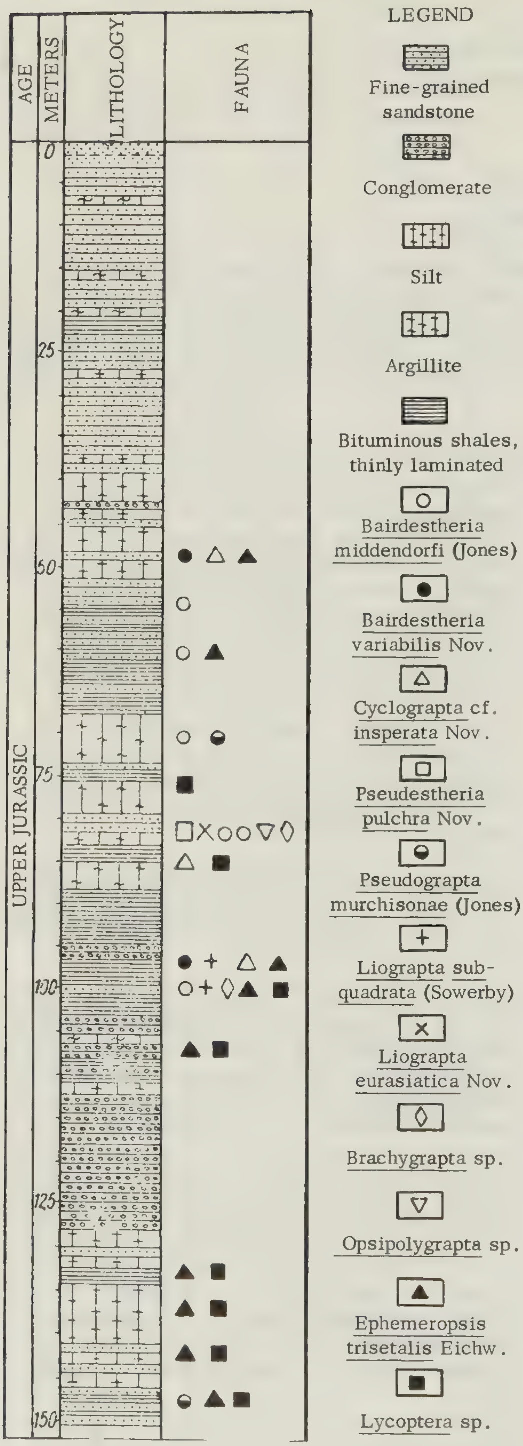


FIGURE 1. Columnar section of Mesozoic sediments taken from a drill hole in the Tugnuy basin

Bairdestheria middendorfi Jones, Bairdestheria variabilis Nov., Bairdestheria sp., Cyclograpta sp., Cyclograpta cf. insperata Nov., Pseudestheria pulchra Nov., Pseudestheria sp., Pseudograpta murchisoniae (Jones), Pseudograpta sp., Liograpta subquadrata (Sowerby), Liograpta eurasiatica Nov., Brachygrapta sp., and Opsipolygrapta sp.

By comparing the section with those of other regions, particularly with those of Mongolia, we established that it contains fauna believed by geologists to be in part Upper Jurassic and in part transitional from Upper Jurassic to Lower Cretaceous [5].

Below a conglomerate bed (at a depth of 105 to 130 meters (m) in the drill hole), silts and bituminous shales contain Pseudograpta murchisoniae (Jones), which, according to Novozhilov [5], is Upper Jurassic. Here also the insects Ephemeropsis trisetalis Eichw. occur in great numbers, which, according to A. V. Martynov [4], are Upper Jurassic. Prints of Lycoptera sp. do not indicate any exact age. These fauna lead us to believe that the layers at a depth of 130 to 150 m are Upper Jurassic.

The bituminous shales, sandstones, and silts overlying the conglomerate beds also contain phyllopods similar to those found in Mongolia. Here Bairdestheria middendorfi (Jones), Bairdestheria variabilis Nov., Cyclograpta cf. insperata Nov., Pseudestheria pulchra Nov., Pseudograpta murchisoniae (Jones), Liograpta subquadrata (Sowerby), and Liograpta eurasiatica Nov. were determined. The presence of Ephemeropsis trisetalis Eichw. was also described in the Anday-Sair (Anda-Khuduk) in Mongolia by Kokkerell [Tr: Coquerel?].

Bairdestheria middendorfi, Bairdestheria variabilis, Pseudograpta murchisoniae, Pseudoestheria pulchra, and others occur in great numbers. As determined in the Mesozoic sections of Mongolia [5], this fauna is Upper Jurassic.

Liograpta eurasiatica and L. subquadrata, which were found by Novozhilov [5] in the Anda-Khuduk series in Mongolia and identified as transitional from the Upper Jurassic to Lower Cretaceous, occur rarely in our section.

Overlying the conglomerates are sediments containing the fish Lycoptera sp. and the insect Ephemeropsis trisetalis Eichw. This group of fauna is common in Upper Jurassic sediments, the majority of the forms occurring in the extreme upper parts.

In view of this, we believe the sediments of the Gusino-Ozersk series in the interval from 50 to 110 m (fig. 1) to be Upper Jurassic, equivalent to the upper Volga formation of the extreme upper part of Upper Jurassic. It is possible that the boundary between the Jurassic and Cretaceous

sediments in this region is not a line but a transitional zone of apparently small width.

The bituminous shales were also studied in the region of the Lake Gusinoye. Here, in the M. Khayan canyon, the silts which are stratigraphically from 2 to 3 m higher than the bed of bituminous shales contain phyllopods determined by Novozhilov to be Opsipolygrapta jeholensis (Kab. and Kus.) and Opsipolygrapta chii (Kab. and Kus.). The beds containing these fauna are perhaps synchronic with the top of the Zhekhol series or with the top of the Quóngsan formation of Kora, which in both cases represent the bottom of Lower Cretaceous. Consequently, the bituminous shales of Bain-Zurkhe mountain must be considered the lowest horizon of Lower Cretaceous, not as the middle horizon.

Thus, according to the phyllopods studied, the period during which the bituminous shales of this region were formed was long and included the Upper Jurassic and Lower Cretaceous, but was not restricted to the middle of Lower Cretaceous, as is believed by Martinson [3].

The original material of the bituminous shales was not deposited in all the basins of the region and where it was deposited it was not exactly synchronic; however, the deposition was restricted to the time between the top of the Upper Jurassic and the middle of the Lower Cretaceous. The length of the period of deposition of bituminous shales is also indicated by the substantial thickness of the sediments in some places.

In the Gusino-Ozersk basin and in the southwestern part of the Tugnuy basin, the bituminous shales are underlain by coarse conglomerates (figs. 1 and 2). The same is true in the Borgoy basin (S. M. Zamarayev, 1956), where the facies equivalent of the bituminous shales are underlain by a thick bed of coarse conglomerates. According to the available data, this fact occasionally does not coincide with the broad distribution of bituminous shales. Apparently, in the second half of the Upper Jurassic age, the transportation of the clastic material was accelerated. This led to the formation of coarse-grained facies. Gradual peneplanation made possible the deposition of clays and biogenic materials of which the bituminous shales were formed.

Increased gradient from the ranges to the basins produced thick and coarse conglomerates (up to 100 m thick in the Borgoy basin). The elevation of the ranges was apparently related to a short tectonic event, accompanied in places by basic lava flows (in the Borgoy basin).

The conglomerate deposition took place simultaneously in the basins of Borgoy, Gusino-Ozersk, and Tugnuy; that is, within a broad territory. Thus, the tectonic event was apparently caused by one of the unusual regional tectonic phases of one tectonic cycle.

The upwarping of the ranges then slowed and the sharp contrasts in the relief gradually disappeared because of erosion. Sagging of the basins continued, but at a slower rate. These combined processes resulted in the formation of peneplains. The peneplains reached their final form after a relatively long period, which differed from basin to basin because of differential rates of erosion.

The next tectonic phase again elevated the ranges and the basins sagged still more. However, in Lower Cretaceous, as in Upper Cretaceous times, the tectonic development was not uniform. The sedimentation of the Gusino-Ozersk Series, which comprise the upper part of the effusives and sediments of the Mesozoic basins, are apparently alternated by tectonic events in a certain sequence, because periods of slower and faster movement can be recognized.

The study of the geological history of the Transbaikal region includes, as an important part, the stratigraphic division of Mesozoic continental sediments.

Martinson [3] distinguishes biostratigraphic complexes of Middle and Upper Jurassic, Lower, Middle, and Upper Cretaceous ages. In some places, these complexes are interfingered. This can be seen in the section of Mesozoic sediments, for example, in the district of Lake Gusinoye (fig. 2), which has been studied by many geologists. In this section, the fauna forms occur (from bottom to top) as follows:

1. The unionids were found in the dump of shaft 2 on Gusino-Ozersk mountain and determined by Martinson [2] to be possibly Upper Jurassic.

Having studied the Mesozoic fauna in the Gusino-Ozersk basin, Martinson concluded that coal beds of Gusino-Ozersk are to be identified as Upper Jurassic, that is, younger than the coal beds of the Tamchinsk district, for in the latter he discovered Cyrena shantungensis, Cyrena sp., Unio obrutschewi, and Plicatounio nakatongensis Kab. and Suzuki.

2. Ferganoconchs. In the saddle of Tashir (the Bain-Zurkhe mountain), during 1951 to 1954, Martinson collected F. sibirica Tsch., F. subcentralis Tsch., F. anodontoides Tsch., F. estheriaeormis Tsch., F. minor Mart., and covers of gastropods Bithynis sp.

In 1955, in the Nakhodka canyon, we found the same F. sibirica Tsch., F. subcentralis Tsch., F. cf. anadontoides Tsch., F. cf. curta Tsch., and covers of gastropods. Ferganoconchs are, according to Martinson, Middle Jurassic, although

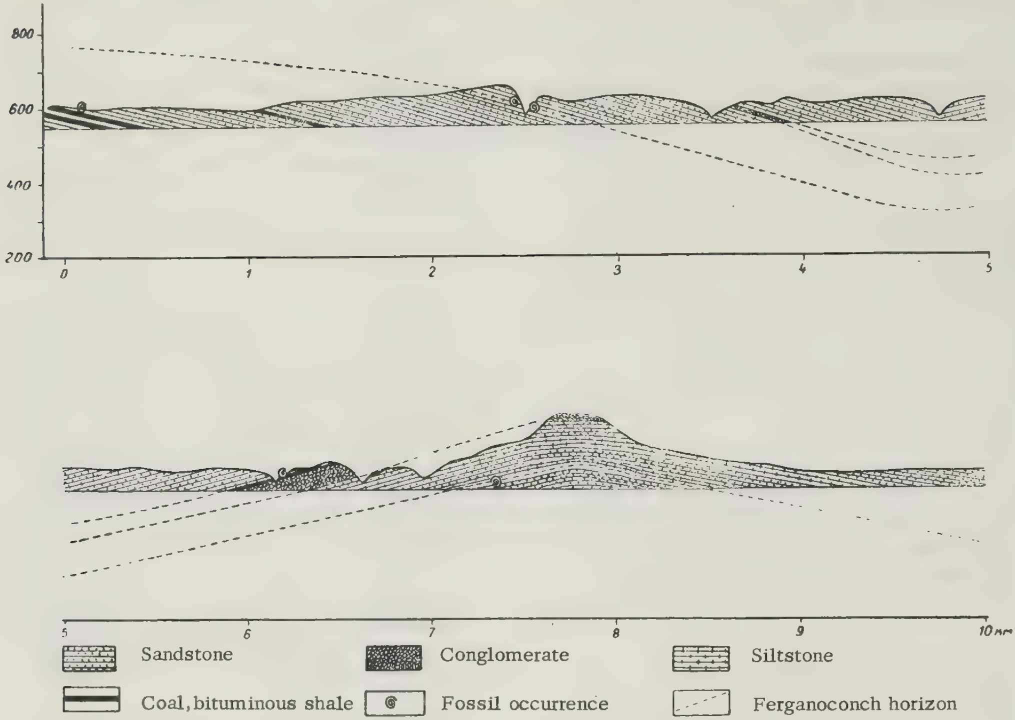


FIGURE 2. Geologic cross section along the eastern shore of Lake Gusinoye

he never found Cyrena and Unio, which he believes to be Upper Jurassic and Lower Cretaceous [2], in the Middle Jurassic sediments.

3. The fish Lycoptera fragilis Gusj. have have been found in the bituminous shales in the canyon of Ara-Ganga.

4. The phyllopods Opsipolygrapta jeholensis (Kab. and Kus.) and Opsipolygrapta chii (Kab. and Kus.) have been found in the canyon of M. Khayan and identified by Novozhilov.

Thus the fauna groups distinguished by Martinson and believed to be of different ages have been found together in the same beds. Particularly, the occurrence of ferganoconchs stratigraphically higher than unionids may indicate that the ferganoconchs occur not only in Middle but also in the Upper Jurassic sediments or the unionids occur in both Middle and Upper Jurassic sediments.

Ferganoconchs most likely occur not only in the Middle but also in the Upper Jurassic sediments. At the same time, we must keep in mind that this fauna does not occur in the Lower Cretaceous sediments or in the transitional zone between the Jurassic and Cretaceous sections. This was also noticed by N. A. Florensov [6].

In studying the stratigraphic fauna groups of Mesozoic continental sediments, one has to keep in mind that the stratigraphic boundaries are not sharp, and these fauna groups do not always provide an exact division.

In the case of Middle and Upper Jurassic sediments, the possibility of a mistake was shown by Martinson [1] in his determination of ages of the coal-bearing basins of Tamchinsk and northern Gusino-Ozersk.

In view of the stratigraphic position of ferganoconchs, the coal-bearing beds of the Tamchinsk district cannot be considered older than those of the northern Gusino-Ozersk.

REFERENCES

1. Martinson, G. G., RASCHLENENIYE UGLENOSNYKH TOLSHCH ZABAYKALAYA NA OSNOVANII PALEONTOLICHESKIKH RABOT [ANALYSIS OF COAL-BEARING LENSES OF TRANSBAIKAL IN PUBLISHED PALEONTOLOGIC LITERATURE]: Akademiya Nauk SSSR, Nauchno Zaklyucheniye za 1954 g., Rukopis. Baykalskaya Limnologicheskaya Stantsiya.

2. ________, O RAZNOVOZRASTNOSTI KONTINENTALNYKH OTLOZHENY ZABAYKALYA [ON THE VARIABLE AGES OF CONTINENTAL SEDIMENTS IN THE TRANSBAIKAL REGION]: Akademiya Nauk SSSR Izvestiya, Seriya Geologicheskaya, 1955, no. 2.

3. Martinson, G. G., O STRATIGRAFII MEZOZOYSKIKH KONTINENTALNYKH OTLOZHENY ZABAYKALYA [ON THE STRATIGRAPHY OF MESOZOIC CONTINENTAL SEDIMENTS OF THE TRANSBAIKAL REGION]: Akademiya Nauk SSSR, Doklady, v. 105, no. 2, 1955.

4. Martynov, A. V., O NOVOM MESTOROZHDENII VERKHEMEZOZOYSKIKH NASEKOMYKH V MONGOLII I YEGO VOZRASTE [ON A NEW DEPOSIT OF UPPER MESOZOIC INSECTS IN MONGOLIA AND ITS AGE]: Paleontologicheskaya Instituta, Trudy, v. 1, 1931.

5. Novozhilov, N. I., LISTONOGIYE RAKOOBRAZNYYE VERKHEY YURY I MELA MONGOLII [PHYLLOPODAN CRUSTACEANS OF THE UPPER JURASSIC AND MONGOLIAN LIMESTONE]: Paleontologicheskaya Instituta, Trudy, v. 18, 1954.

6. Florensov, N. A., MESO-KAYNOZOYSKIYE VPADINY PRIBAYKALYA [MESOZOIC AND CENOZOIC BASINS ON THE PRE-BAIKAL REGION]: Avtoreferat Dissertatsii na Soiskaniye Uchenoy Stepeni Doktora Geologo-Mineralogicheskikh, Moscow, MGU, 1956.

Review Section

Brodsky, A. A., HYDROCHEMICAL PROSPECTING FOR COPPER: State Technical Press for Geology and Conservation of Resources, Moscow, 1956, 84 pp., 42 refs. A Review by W. D. Romey[1].

INTRODUCTION

From 1951 through 1954 VSEGINGEO (the All-Union Scientific Research Institute for Hydrogeology and Engineering Geology) did hydrochemical field work around copper deposits in the Urals, central Kazakhstan, and central Asia. The goal of this work was to develop methods by which hydrochemical techniques could be applied to prospecting for copper.

A REVIEW OF EARLIER WORK

N. I. Sofronov did some of the earliest work on dispersion halos (1936). A. A. Smurov investigated the relationship of subterranean waters to nickel deposits (1938). The possibility of using the high acidity and sulfate-ion content of the oxidation zone in prospecting was proposed by A. Ye. Fersman (1940). Hydrogeologic methods in prospecting for oil, gas, salt, polymetallic deposits, and dispersed elements were suggested by A. M. Ovchinnikov in 1947. Ye. A. Sergeyev also worked on polymetallic deposits (1946). A. A. Saukov noted in 1951 that hydrochemical methods had not yet come into wide enough use. Other active Soviet workers include P. P. Klimentov, G. H. Kamensky, and V. I. Smirnov. Among western workers active in this field, the following may be mentioned: H. E. Hawkes, H. T. Morris, T. S. Lovering, L. C. Huff, H. Almond, J. S. Webb, and A. P. Millman.

THE HYDROCHEMICAL METHOD OF PROSPECTING FOR COPPER

The Effect of Copper Ore Bodies on the Chemical Composition of Subterranean Waters

In the weathering zone, iron and copper sulfides are oxidized to copper sulfate, iron sulfate, and sulfuric acid. The acid waters resulting from these reactions are then neutralized as they in turn react with carbonates, feldspars, pyroxenes, and amphiboles. Other important rock-forming minerals, such as quartz, muscovite, and fluorite, do not react strongly with the acid waters.

Neutralization of acid waters leads to the precipitation of iron, copper, and aluminum sulfates. Waters which have leached out large quantities of metals during oxidation lose much of their heavy-metal content close to the ore body. Even at some distance from the ore body, however, the copper and sulfate ion concentrations and acidity of the waters may be higher than normal. Primary and secondary dispersion halos have the same effect on waters as do ore bodies. Hydrochemical methods may be useful in prospecting for blind ore bodies and ore bodies covered by thick alluvium.

In general, the concentration of metals in the waters decreases with increase in distance from the ore body. However, immediately adjacent to the ore body the concentration may be lower than at some distance from it. This is because the mineral content of the waters depends on the intensity with which compounds are leached from the rocks and the quantity of water passing through the rocks (flow velocity of the waters). It does not depend solely on the concentration of minerals in the rock. Waters similar in chemical composition to the ore water may form at some distance from the ore body causing a ring of higher copper concentration to form far from the actual ore body. This happens primarily when the copper-laden ore waters from the deposit mix with artesian waters instead of with freely circulating ground waters. Trapped in these stagnant surroundings without oxygen, the acid ore waters can no longer hold their copper. Sulfides and native copper preceipitate. As erosion proceeds and these small pockets of copper minerals are uncovered, waters passing through this zone leach out more copper. When these waters, enriched with secondary copper, mix with the other copper-rich waters from the primary deposit itself, a second copper-rich halo appears in the ground waters.

Ore bodies may have various chemical effects on waters. Three types of waters will be considered here:

1. Ore waters are formed by direct oxidation of the sulfide ore body.

2. Acid waters are formed by the oxidation of sulfides in dispersion halos. Both types 1 and 2 listed here have a low pH and are good prospecting indicators.

3. Neutral subterranean waters are the most widespread around ore bodies. Their composition is changed by confluence of ore or acid waters or by the solution of primary and secondary dispersion halo minerals.

Copper mineralization also affects the chem-

---
[1] Minerals Research Laboratory, University of California, Berkeley, California.

ical composition of surface water. The maximum copper content in surface waters is found at a distance of 500-1, 500 meters from the ore body. This results from the confluence of copper-rich subterranean waters with the already copper-rich surface waters.

Hydrochemical Prospecting Guides for Copper

There are six important hydrochemical prospecting guides for copper: 1) increased concentration of copper in subsurface waters (compared to the regional background); 2) increased sulfate-ion concentration compared to background; 3) increased concentration of metals which accompany copper; 4) presence of acid waters; 5) change in type of mineralization of subsurface waters; 6) lowering of pH, change in Eh, and relative increase in potassium concentrations. There are few data as yet on the latter two points. The following six sections will discuss these prospecting guides in detail.

Copper Content of Subsurface and Surface Waters as a Prospecting Criterion

The average copper content of natural waters is between 10^{-3} and 10^{-2} ppm. The higher concentrations (10^{-2} ppm) are usually in swamp waters. In some mineral spring waters concentrations as high as 1-0. 1 ppm have been found. The copper concentration of spring waters issuing from limestones (on the order of 10^{-2} to 10^{-3} ppm) is considerably less than the copper concentration of spring waters from other rocks (1 to 0. 1 ppm).

The large migratory capacity of copper in waters having a high organic content is explained by the increased solubility of copper (the forming of complexes) in the presence of organic acids. For this reason, slowly circulating waters and waters passing through organic sediments or themselves having a high organic content also contain much copper. Observations confirm that swamp waters containing large quantities of organic materials are richer in copper than are other waters. Copper dispersion halos in swamp waters are very wide.

Copper content of ore waters varies widely (from traces to tens of grams per liter). The more acid the water is, the more copper it may contain. Copper sulfates hydrolyze at pH 5. 3. Below this there may be large quantities of copper in the water. Above this point only small amounts can occur.

The most important factors which determine the distribution of copper in ore waters are the following:

1. The content of copper in rocks and ore, the association of minerals forming the ore body, and the percentage of pyrite (FeS_2) in the copper ore; high sulfur and copper facilitate the migration of copper. High pyrite means higher copper concentration in the ore water.

2. The lithologic composition of the ore-bearing rocks: carbonate rocks, for example, cause a low copper concentration in waters because they increase the pH (decrease the acidity) of the water.

3. The intensity of water circulation: where water circulates fast through large openings there will be less copper in the water. Copper content will be higher where fissures are small and the water is kept in isolate spaces within the ore body.

Halos of increased copper concentration in subsurface waters near ore bodies may be interrupted rather than continuous. The nature of the halo depends on the rapidity of water circulation and the mineral content of subsurface waters. Rapid circulation leads to a lower copper concentration in the waters. The chemical composition of subsurface waters may change abruptly within a short distance. Waters having a very high mineral content contain less copper than waters having a low mineral content (all other conditions being equal). The precipitation of $CaCO_3$, $MgCO_3$, and various sulfates causes the adsorption and coprecipitation of copper.

Sulfate Ion as a Prospecting Indicator (Translated in full from the original)

Sulfate ion is one of the usual components of subsurface waters. When the total mineral content of the water increases, it is accompanied by an increase in sulfate. Increase of sulfate content in subsurface waters depends on distance from the water source, salt content of the rocks, and rapidity of water circulation. Increases may also be caused, more specifically, by desulfurization, the presence of gypsum, and the oxidation of sulfide minerals. Desulfurization causes a decrease of sulfate concentration while the other factors mentioned lead to an increase.

Thus the oxidation of sulfides can be one of the reasons for an increased sulfate concentration in waters. If increased sulfate concentration is to be used as a prospecting criterion, the reasons for such increases must be analyzed in detail. Two method may be used to determine what specifically has caused an increase in sulfate concentration:

1. The effect of the above-mentioned general factors (rapidity of water circulation) influencing sulfate-ion concentration may be ascertained. On the basis of this information anomalously high sulfate concentrations, higher than those which would be expected on the basis of geological and hydrogeological data, may appear. High

sulfate concentrations resulting from the presence of gypsum in the rocks must be distinguished. Gypsum in the rocks is usually easily observed because of: a) surface traces (crystals and incrustations), b) characteristic facies relationships within the rock indicating the presence of syngenetic gypsum, c) climatic, hydrologic, geomorphologic, and paleogeographic conditions indicating epigenetic gypsum. It must, however, be borne in mind that gypsum also can be the result of oxidation of heavy metal sulfides.

2. Determining the change of sulfate concentration in comparison to concentration changes of other components of subsurface waters (especially chloride ion) is also useful. When an increase of sulfate concentation has not been caused by oxidation of sulfides, it is accompanied by an increase of chloride concentration. The chloride-ion concentration of subsurface waters does not increase during the oxidation of sulfides. In waters with a low mineral content, the concentration of sulfate ion increases more rapidly that that of chloride ion. As the total mineral content of the water increases, the rate of increase of sulfate concentration decreases while that of chloride increases. This can be illustrated graphically by plotting the sulfate and chloride concentrations against the total mineral content of the water. Once the background sulfate-chloride ratio for an area has been determined, anomalously high sulfate concentrations may appear.

A more detailed discussion of prospecting methods is to be found in Chapter III, section 4. Sulfate concentration may be used only in prospecting for sulfide-ore deposits, and then most successfully for deposits containing pyrite.

Since sulfate concentration is not a specific prospecting indicator for copper, it is used to find prospects. These must then be subjected to further prospecting work for actual copper mineralization.

There are several distinct advantages to using sulfate concentration as a prospecting indicator:

1. High sulfate concentration in subsurface waters around sulfide bodies gives a wide, distinct halo.

2. Within the halo high sulfate concentration connected directly with the sulfide body can be accurately determined.

3. Sulfate halos show up even when the circulation of subsurface waters is rapid.

4. The minimum concentration of sulfate in subterranean waters is several parts per million. Chemical analysis in the field is thus simplified and need not be especially sensitive or accurate.

5. There are simple and rapid field methods of determining sulfate (up to concentrations of 70 ppm) and chloride. Nephelometric analysis may be used for sulfate, and silver or mercuric precipitate may be used for chloride. Determinations of large concentrations of sulfate in the field are less accurate. New methods with increased accuracy are being developed.

The sulfate-ion method of prospecting is especially effective in mountainous areas where subsurface-water circulation is rapid and the total mineral content of the waters is low. Sulfate ion is one of the basic hydrochemical indicators in prospecting for copper.

Metallic Associates of Copper Ore in Subterranean Waters as Prospecting Indicators (Translated in full from the original)

The use of the concentration of metals other than copper in subsurface waters as prospecting indicators depends on the type of copper ore. The metals which most commonly accompany copper are zinc, gold, cadmium, arsenic, lead, silver, and molybdenum (Gudalin and Kovalev, 1951). Gold and cadmium have such a low migratory capacity in subsurface waters that it is difficult to use them as prospecting indicators for copper. Analysis for arsenic in subsurface waters is so difficult that it is also an unsuitable indicator. Lead is very insoluble and is present in only small quantities in comparison with copper. Among the metals commonly accompanying copper, only three are suitable as prospecting indicators in subsurface waters: zinc, molybdenum, and silver. Zinc is considerably more soluble that copper. Its concentration in waters is significantly higher than that of copper. The copper concentration in subterranean waters may be between 1 and 100 parts per billion. That of zinc may be of the order of several tenths to more than one part per million.

Zinc forms wide halos around ore bodies (up to several square kilometers) because of its large migratory capacity. High zinc concentrations may be found at considerable distances from the ore body. The correspondence between high zinc and copper concentrations around copper ore bodies shows up clearly on hydrochemical maps. The concentration of zinc in subterranean waters is used to best advantage in prospecting for pyritic and polymetallic copper-bearing ores. Zinc is customarily present in these.

The migratory capacity of molybdenum is similar to that of copper. However, less molybdenum is coprecipitated with calcium and magnesium carbonates. The molybdenum concentration in waters depends less on the total mineral content of subsurface waters than does that of copper. A map showing the distribution of molybdenum in subsurface waters of a copper-

porphyry district may be used to illustrate the use of molybdenum in waters as a copper prospecting guide. The subsurface-water molybdenum concentrations plotted on the map were obtained by semiquantitative spectrographic analysis. The map shows that the highest molybdenum concentrations were found primarily in waters near the porphyry-copper deposit. Interestingly enough, molybdenum was most often found at water sampling points where subsurface and surface waters from the porphyry-copper deposit flow together (stations 111, 110, 109, 114, 113, 116). These station are in the valley of the large river which serves as a base level for surface and subsurface waters.

Semiquantitative analysis of dry residue from water samples shows that silver migrates in subsurface waters just as easily as zinc. However, the quantities of silver are very small. Broad halos of high silver concentrations may form around ore bodies, but these have not as yet received much study.

High concentrations of metallic associates of copper in subsurface waters may be used to indicate large prospective ore-bearing areas. High copper and sulfate-ion concentrations in waters within these larger areas may be used to outline actual commerical ore bodies. Sometimes metallic associates of copper may also be used in contouring ore bodies on the map. Sufficiently sensitive field analytical methods have not yet been perfected for these metals. Good results may be obtained only by using spectrographic or polarographic analysis. These methods require transportation of samples to a laboratory. Metallic associates of copper ore may thus be used as auxiliary prospecting indicators.

Acid Waters as Prospecting Indicators

Acid waters often indicate the presence of copper. They show high concentrations of sulfate ion, ferrous and ferric iron, copper, and aluminum. They are not direct indicators of copper ore because waters passing through an ore body composed solely of pyrite may show the same characteristics. Acid waters seldom reach the surface and then form only small reservoirs. They are used for prospecting usually in connection with drilling work. In prospecting, the pH of water samples should always be checked as soon as the samples are taken in the field.

Changes in Chemical Composition of Subsurface Waters Used in Prospecting

Subsurface waters near ore bodies are usually enriched in sulfate ion, Ca^{++}, Na^{+}, and Mg^{++}. Large changes in chemical composition of waters are observed only for calcium and sodium bicarbonate-rich waters and occasionally for waters rich in sodium chloride. The following reaction explains some of the changes:

$$(Ca^{++} + SO_4^{=}) + (2HCO^{-} + 2Na^{+}) = 2Na^{+} + SO_4^{=} + CaCO_3\downarrow + H_2O$$

Calcium and sodium bicarbonate-rich waters are characteristic in fissures of igneous rocks. Areas where igneous rocks are found are thus especially suitable for the application of this method. At least five chemical components must be determined (Ca^{++}, Mg^{++}, Cl^{-}, $SO_4^{=}$, HCO_3^{-}). For this reason the method is useful only when the chemical determinations are being made anyway, for example, for a general geochemical map but not as a direct prospecting tool.

METHODS OF CONDUCTING HYDROCHEMICAL SURVEYS AND INTERPRETING THE RESULTS

Uses of Hydrochemical Surveys

In hydrochemical surveying, mass field determinations of pH, Cu^{++}, $SO_4^{=}$, and Cl^{-} in surface and subsurface waters are made in order to establish the hydrochemical background and to find anomalies within it. The most clearcut, easily interpretable results are obtained in deeply eroded terrain containing many isolated basins. Hydrochemical determinations may be carried out along with geological field work.

Hydrochemical Anomalies

A hydrochemical anomaly is a zone where the copper and $SO_4^{=}$ concentrations of subsurface waters are higher than the regional background. These anomalies are established by studying the springs in an area. In hilly terrain, springs at the foot of hills as well as those on the sides of the hills must be sampled. Once an anomaly has been found, it must be followed both upstream and downstream.

Since hydrochemical anomalies do not necessarily indicate the presence of an ore body, the origin of each anomaly must be examined in detail. Anomalies may result from artificial introduction of copper into subsurface waters or from secondary accumulations of copper. Secondary accumulations of copper in subsurface waters may cause intermittent anomalies, if associated with ore bodies; or, on the other hand, they may cause the appearance of an anomaly where there is no ore. Contamination of waters may also cause sulfate enrichment in some zones. High sulfate and low pH without any increase in copper concentration may indicate a pyrite ore body containing no copper. In this case an analysis should be made for the metals commonly associated with copper in case the copper itself has precipitated from the solution for some reason.

Once it has been decided that the anomaly could have been caused by an ore body, the flow direction of subsurface waters must be determined. Generally ore deposits lie above a hydrochemical anomaly (upstream with respect to the flow direction of subsurface water). Possible changes in flow direction of the waters must be considered.

The Place of Hydrochemical Surveys in Prospecting Work

Hydrochemical surveys should be carried out in conjunction with geologic, mineralogic, geochemical, and geophysical prospecting work. Mineralogical prospecting for surface traces of a copper deposit must always be carried out. Gossans and bleached or albitized zones are important prospecting guides. However, all copper compounds forming in the oxidation zone are very unstable and mobile. Thus, all surface traces of copper may have been leached from the area near the ore body. Secondary accumulations of copper may form at some distance from the ore body itself when changing acidity causes the copper compound to precipitate. This greatly complicates prospecting by purely mineralogical means. Hydrochemical methods are particularly effective in this case. They indicate from which direction the copper-rich solutions causing the secondary accumulations have come. In rough terrain a combination of hydrochemical and geologic methods is useful. With a good geologic base map, hydrochemical work may be done independently of a geologic expedition.

Hydrochemical sampling should continue during the detailed surveying work which follows preliminary prospecting.

Running a Hydrochemical Survey

Preparation for Field Work

First of all the area to be surveyed and the methods to be used must be chosen, the literature must be checked, and the field party organized. Any references to acid or sulfate waters should be noted. The locations of springs, depth of the water table, direction of subsurface-water flow, nature of the drainage pattern, and amount of precipitation should all have been studied before beginning field work. Hydrochemical investigation should be conducted at a time when the maximum number of springs is flowing.

Field Investigations

In choosing sample points, the investigator must beware of old mine workings or any areas where a copper anomaly might appear without reference to an ore body. Samples should be taken from every water source in the area being investigated. However, dirty water, old well water, and other contaminated waters should be used only when no other water sources are present. A checkerboard pattern may be used in swamp-water sampling. Whenever surface waters show an anomaly, subsurface waters at this point must be tested also.

In small-scale mapping of areas with abundant springs, the following waters should be sampled: springs associated with a definite sector of the geologic-hydrochemical cross section, springs associated with lithologic contacts, springs in river valleys, swamp water, and surface stream water. Initial samples should be taken where subsurface waters are closest to the surface. Where acid waters are suspected, drilling may be desirable. Changes in copper and sulfate ion concentrations and in pH may occur as a result of rains and melting snow.

Clean sample bottles and corks are essential in sampling. The stoppers should provide a good air-tight seal. Just before taking the sample, the bottle and stopper should be rinsed out several times with some of the water which is to be sampled. A small amount of water taken by pipette from the bottom of the spring should be added to the bottle before closing it. Bottles must, of course, be properly labeled and logged immediately.

Samples should be taken as close to the point where the water flows from the rocks as possible. Changes in acidity, loss of gas, oxidation of some elements (iron, for example), and precipitation of certain compounds all occur as soon as subsurface water comes into contact with the air. The mineral content of waters may differ at different levels within the same stratum. The top layer of ground water may have a higher mineral content than lower layers. Waters passing through strongly jointed and fractured parts of a bed may have a different chemical composition than waters circulating through less fractured rock.

The following methods of sampling different types of water sources may be mentioned:

Water Source	Method of Sampling
Springs	Bottles
Shallow wells	Bottles or the E. V. Simonov sample taker
Shafts	Bottles - Water should be pumped out of the shaft and allowed to filter back before sampling. Stagnant shaft water should not be taken. Never take samples from open streams and pools in old workings.

Water Source	Method of Sampling (continued)
Quarries and old workings	Samples should be taken 2 to 3 meters below the surface in order to get water that has not become degasified. If possible, take samples from points where waters are flowing from the rocks into the workings. (Water-temperature differences may be used to find these points.)
Bore holes	Samples should be taken without flushing of the hole with water or drill mud, if possible. If the hole must be flushed, water should be pumped out until it shows a stable chemical composition. (The concentration of some easily determinable element, for example, chlorine, may be checked periodically until it ceases to change.) A Simonov water sampler may be used.
Stream waters	Samples should be taken where the current is least active.
Swamps	Waters should be taken from the deepest point available. If possible, take sample at points where fresh water is flowing in.

Since water continues to change in chemical composition even while it is in the bottle, it must be analyzed as soon as possible. Certain elements may be oxidized, and others may be reduced in the presence of certain organic components. Fe, Mn, Ca, and Mg may precipitate. Some elements may be adsorbed on the glass walls of the container. In acid waters certain components of the glass may dissolve (Si, Fe, Br, Zr). Analysis should therefore be done directly at the sampling point whenever possible. If the water must be kept and analyzed at a later date, the following precautions must be observed: 1) the water should be sealed in an air-tight container; 2) acidify the water with dilute HCl. Only the heavy metals and Si can then be determined. Chloride ion obviously cannot be determined. If H_2SO_4 is used, $SO_4^=$, HCO_3^-, CO_2, pH, and H_2S cannot be determined; 3) chloroform may be added to slow down biochemical processes; 4) chemical analysis of the total content of the flask must be made. All precipitates must be brought into solution before analysis; 5) care must be taken not to include any fragments of source rock with the sample. Special care must be taken to avoid particles in suspension in the water. Filtration may be necessary at the sample point.

Samples collected for spectrographic analysis must be evaporated in quartz or glazed-porcelain vessels as soon as they reach the field lab. Evaporation may be performed on a sand bath.

In taking samples, the collector must log the temperature of water and air at the sample point. From these data the depth of circulation of the water may be calculated. The depth of water in the spring should be measured as well as the distance from the ground surface to the water. The flow rate of the spring should also be observed. Samples of the water-bearing rock and of impermeable rocks adjacent to it should be taken. A description of the lithology, geomorphology, facies relationships, character of joints, and other factors must be included.

Office Work

Office work must be done during the field season as well as after it. During the field season careful office work shows where gaps in the data exist. Preliminary interpretations of data also help to orient field work as it progresses. Maps should be kept up to date showing copper concentration of waters at all sample points. The relationship between the copper concentration and geologic and hydrogeologic conditions should be determined in each case. The rapidity of water circulation may continuously be checked by regularly observing the concentration of chloride ion. pH should always be plotted. Careful analysis of data will indicate areas where hydrogeologic conditions prevent any effects which an ore body might have on subsurface waters from being observed. Whether high copper concentrations come from ore bodies, dispersion halos, or artifical contamination may also be determined.

The SO_4/Cl^- ratio should always be marked on the map. Curves may be drawn to separate sample points which could be influenced by ore bodies from those which could not. Points where the pH of the water is less than 5 must be marked. When there are known ore bodies in the area which occur under similar geologic and hydrochemical conditions, comparisons between anomalies should be made.

After field work is finished and all data are available, final hydrochemical maps must be made. A hydrochemical profile should accompany the map showing total mineral content of waters. Examples of these hydrochemical profiles are given. They permit the accurate location of ore bodies by using all possible data to best advantage.

Final Report

The final report should include a map, chapters on the total mineral content of waters in the area studied and on the nature of hydrochemical anomalies observed and their possible connection with ore bodies, remarks on areas where further prospecting should be done and where reconnaissance drilling could profitably be done.

Hydrochemical methods may also be used in

prospecting for tin, zinc, molybdenum, nickel, and lead. Molybdenum and zinc migrate more easily than copper. Thus, general reconnaissance prospecting for these metals is easier. But contouring and exact location of commercial ore deposits are more difficult.

Notes on international scientific meetings

THIRD ALL-UNION HYDROLOGICAL SESSION[1]

Leningrad, October 1957

by

A. I. Chebotarev and I. V. Popov

• *prepared by the United States Joint Publications Research Service*[2] •

The third All-Union Hydrological Congress was held in Leningrad from October 7 through 17, 1957.

The congress was called together by the Main Administration of the Hydrometeorological Service which administers the entire supporting hydrological network of the country and the central scientific-methodical organ in the field of hydrology of the U. S. S. R. --the State Hydrological Institute.

The basic task of the congress was to summarize the results of the investigations of the waters of the land during 40 years of Soviet power and to determine further paths of their development.

The congress considered problems of the calculation of river runoff and other elements of water balance, hydrological forecasts, hydrophysics (chiefly in the field of the study and development of methods of calculating evaporation, snow, and ice), hydrological regimen of lakes and water reservoirs, hydrodynamics and waterway bed processes, water-economy calculations, moisture cycle of the atmosphere, regional hydrology, hydrometry and instrument manufacture, underground waters and underground feeding of rivers, hydrochemistry, and also sanitary protection of waters and hydrobiology to the extent to which it is related with the problems of the hydrology of the land.

The congress was attended by 1, 295 regular participants of its work, including 1, 260 citizens of the U. S. S. R. who represented 23 nationalities of all the 15 union republics and 35 foreign guests. The total number of those attending exceeded 1, 500 people.

There were 4 full and 111 section meetings at which 427 reports were read.

Representatives were sent to the congress from 406 organizations. The hydrometeorological service was represented at the congress by 60 organizations; of these, the greatest number of reports was by the State Hydrological Institute (86).

Organizations of the Academy of Sciences of the U. S. S. R. took an active part in the work of the congress; first among these were the section for the scientific development of problems of water economy, Institute of Geography, Hydrochemical Institute, and also the Institute of Hydrology and Hydraulic Engineering of the Academy of Sciences, U. S. S. R.

Of the higher educational institutions, the most active participants of the congress were the Moscow and Leningrad Universities and the Leningrad and Odessa Hydrometeorological Institutes.

Participating to a great extent in the work of the congress were the Ministry of Electric Stations, U. S. S. R., with its scientific and design organizations; the Ministry of River Fleet of the Russian S. F. S. R.; Ministry of Communications, U. S. S. R. ; Ministry of Geology and Protection of the Resources, U. S. S. R. ; and the Academy of Medical Sciences.

Participating in the work of the congress were also representatives of the Geographical Society of the U. S. S. R. , scientific-technical society of water transport, power industry, and other organizations.

The meetings of the congress were attended by representatives of the central and Leningrad party organizations, councils of national economy of the Leningrad, Karelia, Perm, Dnepropetrovsk, Zaporozhye, Stalinsk, and Tashkent economic administrative regions.

The State Hydrological Institute, with the participation of other organizations of the hydrometeorological service; Academy of Sciences, U. S. S. R. ; scientific and design organizations of different departments, factories, and shops, prepared an exhibit showing the state and accomplishments of hydrology during 40 years of Soviet power. Altogether, 35 organizations participated in the exhibit.

The exhibit aroused great interest. The register showed many positive comments about the exhibit and wishes for the publication of its

---

[1] Translated from III Vsesoyuznyy Gidrologichesky Syezd: Meteorologiya i Gidrologiya, 1958, no.2, p. 57-60.

[2] JPRS (NY) L-466.

data in the form of an album.

Deserving note is the organization for the participants of the congress to view films of hydrological subjects, including fragments of a film specially taken by the State Hydrological Institute dealing with experimental hydrological investigations.

A comparison of the structure and subject matter of the second and third All-Union Hydrological Congresses gives a graphic picture of the development of hydrology as a science.

At the first congress, 166 reports were read on the hydrology of the land; at the second, 201; and, at the third, 427.

The substantial increase in the number of reports on problems of calculations and forecasts of the runoff (from 17 reports at the second congress to 82 at the third) indicates the great development of work in this field. There was an increase also in the number of reports on hydrophysics: from 19 at the second congress to 60 at the third congress. There was increase of more than twice in the number of reports on the investigations of lakes and water reservoirs (from 20 to 42).

A great increase in the number of reports is noted with respect to problems of hydrodynamics and waterway processes (from 20 to 53); moreover, there was an expansion also of the circle of problems under consideration. If at the second congress these problems had still a predominantly somewhat abstract hydraulic-mathematical aspect, then at the third congress, the reports encompassed a wide circle of problems of hydrodynamics, morphometry, morphology, modeling, and laboratory and natural investigations.

On 16 private and brief communication on the problems of water economy calculations were made at the second congress, whereas, at the third congress, considerably broader problems of the water economy were discussed; moreover, the number of reports increased to 33.

The reports on the problems of general hydrology of the second congress were limited to an examination of the regional runoff hydrological characteristics for a limited number of regions. At the third congress, the reports examined a wide circle of problems of hydrology, from general problems of methodology to the results of investigations of individual elements and aspects of hydrological processes.

Reports on hydrometry included various, entirely new problems, as for example, calculations of the runoff at hydrotechnical structures, use of aerial photography in hydrological investigations, radioactive methods, and others.

Reports at the third congress dealing with underground waters cast light on the problem of feeding of rivers and consideration of the relationship of underground and surface waters during hydrological calculations and forecasts of water regimen.

A considerably greater endeavor in the study of the waters of the land and the solution on this basis of various national economy problems are peculiar also to reports of the hydrochemistry of natural waters. Great attention was paid to problems of sanitary protection of waters. The number of reports on hydrochemistry increased from 12 to 28.

The large number of reports read at the 11 sections and subsections of the congress made it difficult to a certain extent for the participants to encompass directly during the course of the congress all the problems of hydrology. It is necessary, however, to keep in view that the contemporary state of hydrology, which is characterized by a wide development of independent branches, makes possible a sufficiently deep consideration of these only within the frames of each branch. The congress satisfied completely such an arrangement of the problem. The works of the congress, which are planned for publication, will undoubtedly be a sort of hydrological encyclopedia, essentially for multifaceted scientific generalizations and conclusions. To a certain extent, such generalizations have already now found their reflection in decisions of the congress.

The reports heard showed as a whole the high theoretical level of Soviet hydrology, its advanced position in world science, and practical directivity of hydrological investigations to the solution of concrete engineering problems.

An important result of the congress was the establishment of creative contacts which assure the development of agreed common opinions on the further directions of the development of the investigations of the most diverse problems of the hydrology of the land. A unanimous opinion was expressed regarding the desirability of establishing a much closer coordination of work, creation of special organs for the approbation of numerous methods of hydrological calculations, creation of single centers for planning the utilization of the water resources of the country and for the protection of natural waters.

The congress noted the inequality of the formally statistical approach which still exists chiefly in individual engineering hydrological calculations and underscored the need for a physical approach to the study of hydrological processes and phenomena. The physical approach gives a reliable base for the wide use of statistics, including the characteristics of probabilities and geographic generalizations of hydrological data.

Such an arrangement of the problem does not at all contradict the statistical and generic methods but indicates the need of their harmonious combination. Although the idea of the unity of natural waters never caused any arguments and received wide acceptance, its practical application remains unsatisfactory.

The congress noted the concrete program of a closer joint study of surface, underground, and atmospheric waters. Decisions were made of the need for a substantial expansion of the network of hydrological stations which carry on observations of the regimen of underground waters, its close relationship with the hydrometeorological network, and also the intensification of investigations of underground waters during the study of the runoff.

From the concept of the unity of natural waters, there follows the recommendation by the congress regarding the development of the problem of forecasts on the basis of a wide utilization of synoptic methods and an analysis of the atmospheric circulation and also consideration of the hydrogeological conditions, the need for wide and systematic publication of meteorological data used in hydrological calculations and forecasts.

It was established at the congress that different points of view regarding problems of hydrological investigations and theoretical positions are the result of an insufficiency of original actual data of the calculations and schematization of the phenomena. The congress made various recommendations directed toward the elimination of these gaps. Moreover, in the decisions of all the sections of the congress, special attention was paid to the need for a wide and planned study of little investigated areas by increasing the network of supporting observation points, specialized runoff stations, and by means of expeditionary work with their mandatory and close combination with stationary investigations.

A new aspect is given to the hydrological investigations by the problem of the control of waters. New objects appear on the map of the country--water reservoirs which introduce substantial changes in the natural situation of extensive territories and lead to the need for the development of new methods of investigations, calculations, and forecasts.

The third All-Union Hydrological Congress underscored the importance of this problem and pointed out the need of organizing wide investigations for its most rapid solution. The problem of the study of the transformed water regimen includes not only investigations of the very regulated reservoirs but also an evaluation of the influence of the economic activity on the watersheds, and problems of the utilization of hydrotechnical structures to take into account the runoff.

In connection with the development of large power systems on the territory of the U. S. S. R., which encompass extensive natural areas, the important problem facing hydrology is the study of secular variations of the runoff and their synchronism for the control of hydroelectric power output.

The problems of hydrological districting also retains an important significance.

The fulfillment of wide measures for the control of water sites gives great significance to problems of waterway process.

Along with individual problems of hydraulics and morphology of rivers and water reservoirs still outstanding, special attention should be directed to the development of common bases of the theory of the waterway on a hydraulic-morphological basis, which requires close relationship of the investigations being carried on in hydraulic and morphological directions.

The great scope of work in the investigation of hydrological processes on little studied territories, at new water sites, and also the need to study the more refined and diverse sides of these processes, require special attention to the sharp improvement of the methods of conducting and programming hydrological investigations.

Field and laboratory experiments under these conditions acquire tremendous significance and require a perfect technical base, which is underscored in the decisions of the congress.

The congress also pointed out the need of the wide incorporation into hydrological investigations of aeromethods, radioactive methods, luminoferous materials, radar, and other accomplishments of modern science.

Within the limits of one paper, it is very difficult to include the whole circle of problems dealt with at the congress and the above-cited problems are only an illustration of the work of the congress and of its decisions.

In conclusion, we wish to point out the most pressing problems discussed at the congress.

The discussion revealed an insufficient study of the problems of the formation of maximum rain consumptions, which led to an abundance of individual means for solving the problem of the calculation of rain maxima, not confirmed by experiment. There is an acute need for the development of a general theoretical basis.

The congress noted the need of an objective comparison and evaluation of existing methods of calculation and intensification of investigations of the processes of formation of rain runoff.

The problem of the influence of economic activity on the runoff by means of agricultural-forest meliorative measures also belongs to discussion problems because of the lack of original data. The congress pointed out the need of attracting to this problem a large number of specialized stations and organizations.

The discussion of the role of underground runoff in feeding of rivers lead to the conclusion of the invalidity of the views of the exceptional role of this source of feed.

A consideration of the existing methods of evaluating the correctness of forecasts has shown that they do not completely reflect the specificity of water economy requirements. Decisions were made of the need to develop new methods for the evaluation on the basis of joint work of hydrologists and water economists.

Various problems in the field of evaporation were also discussed. Thus, diametrically opposite views were revealed regarding the influence of water plants on evaporation.

The discussion of the methods of calculation of evaporation from the water surface revealed the insufficiency of the modern theory of evaporation for the development of reliable systems of calculation, which so far are possible only on the basis of wide utilization of experimental data. The congress proposed to unite the efforts of the State Hydrological Institute and the Main Geophysical Observatory for work in this direction.

The congress found lack of agreement of views regarding the problem of the water balance of Lake Sevan and it revealed the need to attract to this problem the central research organizations.

A discussion also developed on the procedure for taking into account the runoff at hydrotechnical units, in particular the problem of the need of checking the data of the runoff at State Electric Stations, obtained from the operating characteristics of the turbines and water openings of the State Electric Stations. The section of hydrometry came to the conclusion, as a result of the discussion, that there is a need for taring the turbines and the water outlets.

As regards the problem of the waterway process, it was noted at the congress that waterway hydrology develops in sharp fundamental conflict of opinions, which facilitates universal illumination of the essence of the problems under consideration.

The decisions of the congress should find reflection in the activity of all the basic establishments and organizations which conduct hydrological investigations in the U. S. S. R. It is necesary to point out that the results of the congress were the object of discussion by the staff of the Main Administration of the Hydrometeorological Service. As a result of this, a special order was issued within the Main Administration of the Hydrometeorological Service which requires the application of various important measures directed toward the fulfillment of the decisions of the congress.

CORRECTION

COLLOQUIUM ON THE TOPOGRAPHY AND GEOLOGY OF THE DEEP-SEA FLOOR, Nice, May 1958, by Robert S. Dietz, International Geology Review, v. 1, no. 1, p. 113, January, 1959.

Through oversight, Roger H. Charlier was omitted as among the U. S. participants to the French International Colloquium of the Topography and Geology of the Deep Sea Floor reviewed in volume 1, number 1 of the International Geology Review. As a French-speaking American, Charlier played a very useful role in translating discussions and helping to fill the language gap at this international meeting. --Robert S. Dietz.